THE UNIVERSITY OF ALBERTA

THE DEVELOPMENT OF A HANDBOOK FOR WELDING THEORY

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "The Development of a Handbook for Welding Theory," submitted by Gower Allan Kennedy, in partial fulfilment of the requirements for the degree of Master of Education.

Abstract

This developmental research incorporated in a welding theory handbook of sequential welding material, is presented hopefully as a contribution to the changing needs of vocational education students. The format of the handbook has been based on collated information, accumulated by means of the Delphi technique, in addition to results of cooperative studies made through surveys; and active participation of tradesmen, students, instructors and business corporations.

The surveys and studies were carried out in accordance with a PERT form of procedural design and dependent on the results gathered at a position "G" on the PERT path; as the indicator for the need to compile a handbook for welding theory.

Communication with suppliers of welding equipment and accessories, and manufacturers of ferrous and non-ferrous metal; provided the source for current information on new and improved equipment and material.

Data on existing text materials used in the schools for welding was obtained from a large southern Alberta vocational school, a community college and the two Alberta institutes of technology.

A questionnaire was sent to fifteen instructors presently teaching welding within the parameters of the study. The sample was selected, based on various lengths of

instructional experience, for the purpose of evaluating any recent or significant changes which may have occurred recently in the instructional procedures covering content and sequence.

The questions asked (based on the interpretations and results of the questionnaires carried out by the Delphi technique) were formulated for the purpose of obtaining a consensus of opinion from qualified instructors in regard to the sequential presentation of the handbook in terms of major and minor content.

A suggested content list; consisting of major and minor headings was forwarded by mail to the fifteen instructors for their further consideration. It was possible to organize a table of contents of preferential and sequential materials, after tabulating these results and a further screening of the current and obsolescent information previously accumulated. For the most part the latter was obtained through the cooperation of the welding equipment suppliers who had been approached initially as indicated in the procedural PERT design.

The result of the total study led to the conclusions that welding would continue to be an important factor in the industrial world of change; and that a welding theory handbook containing presently acceptable, new data and possible projections for the future, arranged in a suitable sequential manner would contribute effectively to more meaningful welding instruction. It also appeared evident that rapid technological changes and metallurgical innovations would necessitate the review and updating of materials periodically.

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Chapter 1

The Problem

Introduction

A report of the special committee of the Senate on Manpower and Employment was presented in 1962 as follows:

> In order to be effective, vocational and technical training should be carefully planned and must be based on the most reliable estimates of future job requirements. However, it is important to bear in mind that forecasting is fallible, and that even under the best conditions one cannot hope to predict precisely the skills which will be in demand five, ten, or twenty years from now. In view of this, emphasis should be placed on flexibility. As much as possible people should be given the sort of basic training that will permit them to move with the times. Specialization is essential and unavoidable in the modern economy, but a sound balance must be achieved between specialization and adaptability. This is easy to say and much more difficult to implement. Nevertheless, this should be one of the guiding principles in any programme of vocational training. We must prepare people for a world of work that is continually in evolution (Hon. J. R. Simonett, 1963, p. 20).

The strides made in Technical and Vocational Education in Alberta since 1961 are a testimonial to a well developed and initiated plan. Figures received from the Registrar's Office at the University of Alberta, indicate that during the period 1962-1971, a total of 1,387 industrial arts and technical vocational teachers with Alberta teaching certification have entered the field of education to instruct in high schools and various other institutions. The above total, broken down into 527 industrial arts and 860 vocational educational teachers, is an extension of a study mentioned in

a thesis, "A Description of Vocational Teacher Preparation," written by L. J. Shields (1970).

The majority of these teachers, as certified journeymen tradesmen with university entrance requirements, were considered well equipped to instruct in their trade areas. This statement is substantiated by L. J. Shields who states:

> For each year from nineteen hundred and sixty-two through nineteen hundred and sixty-six the percentage of students scoring 65 or more in student teaching was higher for vocational students than for all other students (1970, p. 69).

These same teachers however, were frequently required to organize theoretical information for instructional and training purposes which resulted in curricula based on the biases of the individual instructor.

It should be noted that in many cases information and course outlines were readily available, but to many of the more innovative teachers and instructors, the material provided appeared to be very inadequate in terms of providing students with up-to-date knowledge in their field.

In the area of welding, particularly, vast technological changes coupled with space age metallurgical inventions, precluded the possibility of productive and constructive training unless adequate means of upgrading of course material was implemented.

Henry B. Schacht, in an article from Business Horizons states:

> the rate of change, spectacular as it has been, is bound to accelerate in dimensions that we cannot even begin to dream about (1970, pp. 29-34).

In order to handle change and uncertainty, educators must be prepared to view instructional materials as possibly obsolete, or at least impractical in its sequential and present form.

In a manuscript, "Introduction to the Foundations of Education," (Anderson, Hutchinson, Lawson and Swift) the following implies that educators must prepare to change:

> This rapid change has far reaching implications for education. Not only is there much more knowledge to be taught in schools, but also a continuing need to constantly revise it as it becomes out of date or is seen to be wrong (1969, p. 34).

The author intends to research the current and future welding techniques used in industry, and hopefully to develop a welding theory handbook, by compiling this researched data in a preferential and sequential manner, designed to assist all levels of personnel subscribing to welding programs.

Statement of the Problem

At the present time a very limited amount of theoretical welding information is available, which has been developed to satisfy the instructors' specifications, and in a required sequential manner to optimize learning.

However, many companies who manufacture and supply welding equipment and accessories have manuals and brochures available, on request, which cover information and procedural methods, supplemented by line drawings and other graphic forms.

While researching the available material it was found

in many cases to be:

(a) too highly technical for students at the high school vocational level.

(b) available in limited amounts within the parameter of the study; thus making it impossible to supply all students at one time.

(c) in minimal use where these and other factors did not encourage instructors to teach beyond set course guidelines.

For these reasons it was necessary to research all available data (both old and new) in order to compile in an understandable abstract form the content considered valid and valuable for vocational students in collaboration with experienced welding instructors and industrial practice.

Conceptual Framework

The apparent lack of suitable sequential material for the purpose of introducing the student to the welding trade has been a problem, not only in vocational schools, but in other institutions of vocational training. Estabrooke and Karch, writing on "250 Teaching Techniques" are in accord with the sequential approach to learning and they state:

> Subject matter should be arranged so that the students can learn, step by step, from the simple fundamentals to the more difficult phases of the work. An instructor should present the easier teaching points at the beginning of the lesson to develop students' confidence in their ability to learn (1969, p. 18).

Subject information presently available to the teacher or student are derived from:

(a) Text books; many of which have not been revised for

many years.

(b) Hand-out sheets; developed periodically by individual instructors, and eventually compiled for instructional purposes. Based on an individual and subjective approach in developing the material has often been less than satisfactory.

(c) Informational literature from industrial companies. This is a useful source of material, but does not appear to be utilized in all instructional areas, especially the schools within the parameter of this study.

Many instructors with teaching certification from the University of Alberta in the Industrial Arts and Vocational Educational Training Programs, and extensive experience in the field of their trade, have had little or no opportunity to become involved in helping to set realistic welding theory standards relevant to the modern world of work.

Tests for welding apprentices are currently based and developed from the subject material approved solely by institutions or colleges in the Province of Alberta. A sequence of tests has been developed for the first, second and third year welding apprentices, which can be presented without duplication. The upgrading or updating of these standard tests have, at this point in time, been infrequent.

Leadership from the Faculty of Industrial Arts and Vocational Education in the University of Alberta could be the stimulus needed to continue to meet the challenge of change. Stronger emphasis on attitudes of flexibility and relevance to a world of work in continuous evolution appears

to be required at all levels if the student is to cope with that world as described by Simonett (1963). Recommendations from the educational department could encourage development to improve standards and approaches in theory and in practice. A dynamic influence is essential if the student is to meet his ultimate goal, a realistic role in the world of work.

It has been mentioned by Schacht (1970) that in order to cope with changes, and to meet the requirements of both industry and society, educators at all levels must be prepared to evaluate not only the effect and efficiency of instruction, but also the effect and efficiency of the materials available; in order to provide a maximum opportunity for students to face changes amply equipped.

It must also be considered, that many institutions regard the theory standardization approach as a threat to their autonomy. However, a deep need appears to exist and instructors within these institutions, from the information to date, chose to subscribe to a more effective approach to achieve theory standardization.

Objectives

The purpose of this study is to present from available information, an instructional guide in the form of a handbook, developed to provide teachers and students with a current preferential and sequential welding theory.

Specific objectives. (a) to develop an acceptable standardized welding theory handbook.

(b) to research available sources of data for current and other suitable welding theory information.

(c) to present welding theory in a sequential manner in order to facilitate practical application.

(d) to design a "loose-leaf sectional sequence," which presents all information and allows the addition or rejection of material as desired (up-dating procedure).

(e) to establish an instructional time weighting factor, on each section of the prescribed content for course study purposes.

(f) To develop a suitable evaluation system for the purpose of testing the students' comprehension of theory presented in the time allotted.

Questions to be answered. Answers to the following questions from representatives of industry, welding instructors, students and welding apprentices were essential in order to fulfill all objectives:

(1) Would a welding handbook of acceptable and sequential material be an asset to vocational and/or industrial instructors and students in the schools or other institutions?

(2) What type of welding information would be most helpful in a welding theory handbook, in order to accommodate the needs of the welding teachers and students in the Alberta educational system?

(3) Where and in what manner should currently acceptable up-dated material be obtained in order to fit the needs of such a handbook?

(4) What implementation procedures would be necessary to include additional new data in a handbook, if and when it becomes available?

(5) In what sequence would the theoretical material be most suitably placed, in order to benefit both student and teacher?

<u>Delimitations of the Study</u>

The surveys required to provide the information for an acceptable welding theory handbook were delimited to the following:

(1) The parameter for the source material encompassed sixty-two national and international publishing companies, welding material wholesalers, and reputable welding equipment supply houses.

(2) An area south of Calgary, as mentioned in the PERT network, for teacher, student and apprenticeship survey purposes was recommended as appropriate. It was selected for the purpose of providing data from a rural area, unaffected by possible implications due to close proximity to the senior institutions in Alberta.

(3) The teacher and journeyman population for research purposes was selected from those presently active in the teaching and trade areas both within and outside the parameters of the study.

(4) Those students presently enrolled in a welding course within the designated parameters.

Definition of Terms

For the purpose of this study and development of the subsequent welding theory handbook the following definitions are employed:

Welding. The definition of the term welding as given by The Welding Encyclopedia (1961 edition, p. 814) was found to be acceptable for the study. The Welding Encyclopedia defines welding as:

> The process by which two pieces of metal are united by heating them to a melting temperature and causing them to flow together.

Theory. For the purpose of this study, theory is defined as systematically organized knowledge which explains the basic "why" without excessive and unnecessary detail. Emphasis is placed on the "how-to-do-it" principle, because we learn by doing.

Handbook. A book providing specific information in a sequential form for instruction, learning and reference purposes.

Limitations

The development has been somewhat confined or restricted, not so much to the time allotted but by the funds available for carrying out the number of surveys, as outlined in the Procedural Design.

Assumptions

Since the companies were contacted, not only for the purpose of obtaining up-to-date welding material, but for the purpose of forecasting future welding needs by means of the Delphi technique, they were selected because of their reputed cooperative approach to education. It was assumed that the information supplied, together with the comments on the questionnaire, would be invaluable to students and teachers.

It was assumed that the data received from the sample of welding instructors, classified as the primary source due to their training and experience; would be representative of the majority of the total population concerned with welding within the parameters of the study.

The feedback from the students is considered reliable due to the cooperation of the students and teachers contacted, and the manner in which the questionnaires were administered.

It has been assumed that the biases of the journeyman welder have differed somewhat from their student era, due to maturation and job performance.

Significance of the Study

The results of the surveys and the questions to be answered, together with screened research material presented by various authors and industries, were the determinants as to whether the welding theory handbook would be the end product of this thesis.

In many vocations and especially welding, the teacher or instructor apparently has no up-to-date welding theory and

specifications, to ensure competency in teaching students many of the new techniques in the world of work. During a personal student teacher contact presurvey approach, nine of seventeen teachers and/or instructors voiced negative opinions on lack of up-to-date subject matter so vital for competent teaching of new technological techniques.

Wroot mentions, "a considerable emphasis being placed on the need for subject matter competence" (1970, p. 14). Such a statement it appears, should be true of the student as well as the teacher.

Petruk presents a somewhat different approach from researched information. He states:

> Educational literature indicates that there are diverse viewpoints among educational authorities as to what constitutes an adequate preparation for technical and vocational teachers (1967, p. 7).

Wirth apparently agrees with Wroot insofar as teacher competence is concerned. In his book, John Dewey as an Educator, he states:

> Dewey argued that a healthy profession requires teachers who have learned to apply the habits of critical thought to their work. To do this, they must have a full knowledge of their subject matter (1966, p. 56).

An article, "Learning Oriented System of Instruction" written for the Junior College Journal, implies that institutions will be adopting a philosophy of educational opportunity for all--all abilities, all social and economic classes, all interests, and all ages. To this end, content must be selected on the basis of its relevance to the needs of the student.

Should the Alberta Colleges Commission adopt such a philosophy, and should they include the technical institutions and the agriculture colleges under their jurisdiction, as they have the colleges--this in itself will certainly dictate a change in attitude as to what constitutes essential materials in texts, for the purpose of welding programs in these areas.

Any such philosophy must be based on the fact that:

1. No real effort has been made to keep pace with the rapid technological expansion taking place in the trade area.

The above statement is more or less reiterated by Robert J. Marcus (1971, p. 15) in an address at the 23rd annual round table conference of the industrial relations committee of Edison Electric Institute when he said:

> How else has the work force changed? We have discovered that many of our new hires come to us less well equipped to do the job than formerly. For example, in a recent test validation study it was found that applicants for clerical positions were scoring an average of 25 percent less on our clerical aptitude test than had applicants only three years before. This situation was found true in many other vocational areas.

2. Welding theory tests meet only the requirements laid down in traditional and even obsolete books.

In today's society there is an ever increasing demand for engineering data that provide means for more efficient containment according to W. D. Doty (1965) writing in the <u>Welding Journal</u> on the topic "Welding of Quenched and Tempered Steels."

Anderson, Hutchinson, Lawson & Swift have indicated indirectly that realistic testing cannot take place without

up-to-date material. They state:

> This rapid change has far reaching implications for education. Not only is there much more knowledge to be taught in schools but also a continuing need to constantly revise it as it becomes out of date or is seen to be wrong. The teacher in the school must be adapting himself and his methods to the changing society (1969, p. 34).

3. The knowledge and increased abilities of the students living in a technological age are not recognized.

This statement is substantiated by John B. Teeple in a speech given at the AAJC Regional Occupation Education Conference, New York, April 16, 1969 on the topic "Variables in Planning Occupational Education Programs." In his speech Teeple said:

> Nobody should pretend that incorporating students in planning is easy, for if they completely agree with your plans, you can bet they are not representative. You may also have to learn a new language. In the 1970's students may be the most important and most vocal variable in occupational planning. But after all, it is their education and not ours, and given today's domestic situation, I cannot convince myself that our answers are necessarily right or the methods we practice appropriate.

4. Educational advisory committees from the trade areas are geographically oriented.

Although this is felt to be a most unfortunate situation, especially where the mobility of trained students encroaches on areas where the learned skills are invaluable, some benefit from such committees, according to Cicely Watson have merit. In regard to Ryerson Institute of Technology, Watson says:

> By using a series of advisory committees for its programs, Ryerson was assured of being "au fait" with the latest thinking in the business or professional fields concerned and of having instructors who were professionally reputable (1971, p. 36).

For these reasons alone it appears necessary to at least research the type and materials readily available to the new instructors.

It is significant therefore to make some effort as early as possible to establish, within the parameter of the study, (a) if a problem exists and (b) how the problem may be solved.

Chapter 2

Review of Related Literature

P. R. Mort and D. H. Ross in their book, Principles of School Administration have stated:

> There is nothing impractical about good theory . . . Action divorced from theory is the random scurrying of a rat in a new maze (1957, p. 36).

The following sections review studies related to the apparent need for a welding theory handbook. The research covers information received through the Delphi method on future trends in welding, in addition to research directly related to such handbook content areas as "Material Sequence," "Safety," and "Time Allocation for Theory Segments."

Need for a Welding Theory Handbook

The aim of education, as reported in the Alberta Senior High School Handbook states, "the prime aim of the school is to assist each Alberta youth in his growth towards maximum self-realization" (1970-71, p. 7). Maximum self-realization however, cannot be accomplished unless the students are made aware of the changes taking place in the vocational areas of their choice.

H. R. Ziel recognizes this need by recommending:

> My contention is that schools should be current in their programs. The interpretation of culture and technology cannot be that of twenty years ago if we are to meet the challenge of tomorrow (1971, p. 7).

To date, a review of the literature indicates that changes are necessary in almost all of the course content currently in use for instructional purposes in every trade area. An article written in the Canadian Machinery and Metalworking Magazine, as early as August 1962, states: "Many new and important developments have appeared since 1958. In some cases, existing processes have been modified for new applications, and in others new welding concepts are being used."

Kidd and Leighbody recognize the need for presenting new or even old material, if relevant, in any manner which helps the students to prepare for the changing world of tomorrow. They stated:

> Throughout the years, educators have developed methods for teaching the youth who come under their charge. These general methods which apply to all subjects are the object of constant examination and study. The end in view is to improve these methods so that the instructor can transmit to the students in the most effective way, the skills, knowledge, and characteristics which make for success (1955, p. 11).

It is apparent from a survey of the literature that no consistent examination of the welding theory teaching material is in effect. The lack of preferential sequential welding theory material (as mentioned previously by Howard W. Sams Publishing Company) may be due to two reasons:

First, a deviation from the traditional often creates anxiety for many teachers and instructors if important preliminary steps in their implementation is omitted or communication techniques poorly handled. This phenomenon was recognized by C. M. Achilles and he states:

> Changes should not be summarily rejected because they deviate from values cherished in the past. Changes must be accepted and implemented if they are responses to new challenges and new value-orientations, and if they are indeed adequate responses to changing needs (1969, p. 22).

Second, rapid changes in welding technology makes constant examination and study difficult. That such changes are continuous, is indeed factual; as mentioned in the article "Technology Forecast '71" in the Metal Progress which states "The shielded metal-arc manual electrode processes will take on new dimensions" (1971, p. 83).

The author's approach where involvement of various groups related to this problem was sought with the focus particularly on immediate and long range needs of both students and teachers was carried out through survey procedures. As a result, pertinent sequential material for a welding theory handbook was compiled; based on information from the following sources:

John C. Sawatsky writing on "Inventing our Training Future, states:

> Most courses, books, films, etc., are designed by academically oriented people (including company trainers) who are on an academic ego trip. So far, they have seldom identified the practical skills which their clients need (1971, p. 29).

In an earlier statement R. McBeath, writing in the Mediator Magazine, stated:

> If we stay pre-technological in our education thinking and practices, we will increasingly lose control of education in our technological society. We will lose it at the policy level to other organizations as they try to meet their needs--needs the schools are not meeting (for example, policy statements on education from industry and commerce). We will lose it at the action level because of apathetic or frustrated pupils

> who, finding no involvement in our classrooms, seek, for example, satisfaction in coaching colleges or escape through the mass media (1970, p. 11).

A statement which supports the previous two and will no doubt gain wide acceptance is that of H. R. Ziel who states:

> As is all good administrative practice, feedback from the teachers who will ultimately implement the program, and a follow-up of students subscribing to the program; should be utilized to establish a reasonable standard of performance of introduction and upgrading of the recommended program. This need for feedback from students and instructors should not be taken for granted or dismissed too lightly. Evidence indicates that many good educational innovations have failed, because a standard of performance, and the complete program; was imposed upon the teacher without the opportunity for feedback. This feedback could result in changes, improvements and modifications because of local situations (1971, p. 7).

Material Sequence

A study was made by the author pertaining to the alleged deficiency of suitable sequential theory information for welding purposes both in Canada and the United States.

Five well qualified instructors, four of whom had vocational educational backgrounds, felt that the surveyed material would not serve all the needs of all students at different levels taking welding courses. John Obst, Education Advisor for the Howard W. Sam Publishing Co., of Indianapolis, Indiana states categorically that the welding trade area is sorely in need of suitable text book materials. Moreover, in its 1972 technical-vocational education text book catalogue, this company has not mentioned or even listed a text book for the welding trades.

G. H. Silvius (1965) recommends in his special vocational educational research project for Wayne State

University, that units of instruction for programs or courses to prepare persons for various service occupations need to be identified and organized.

The need for a sequential material or theory approach to learning for skill purposes is not a recent concept developed since the passing of Bill C-49. Kidd and Leighbody in a discussion on "The Methods of Teaching Shop" have stated:

> The organization of a course as a series of lessons forming progressive steps in a stairway of learning is particularly useful in the teaching of an industrial subject (1955, p. 18).

The ability of the industrial arts or vocational student to enlarge on his knowledge would in part, depend on the organization or sequence of learning material. Herbert J. Klausmeier apparently agrees with this premise when he states:

> The people who outline the general sequence of instruction from kindergarten through Grade XII must give careful consideration to appropriate learnings at each grade level so as to encourage continuity in learning (1961, p. 371).

Klausmeier in a further discussion of the importance of sequential theory, using physics as an example, states:

> Instead, the study of physics in high school must be organized into appropriate segments in which the student learns well; in turn this knowledge, skill, interests, and attitudes enable him to continue further study of physics in college. Eventually he may even become a physicist (1961, p. 372).

The approach of Klausmeier in regard to physics was presented in a similar manner by Rossi (1954) in regard to welding. Rossi was aware of the necessity of placing welding material in a sequential manner for he states:

> The subject matter has been arranged in a progressive sequence; this approach should prove very advantageous in any training program where welding is a consideration, regardless of the number of hours assigned to its fulfillment (1954, p. viii).

W. E. Hathaway apparently sums up the situation by stating, "that a curriculum development technology would reduce the planning task to manageable size by offering a concrete sequence of steps leading to the desired outcome" (1970, p. 59).

Safety

If as stated in the American Welding Society, a good workman is a safe workman, it follows that emphasis on safety measures should be of major importance in the sequential contents of a welding theory handbook.

W. G. Dickson indicates the importance of safety in vocational theory material when he states:

> The accident rate in manufacturing plants throughout the country has been dropping steadily for the last fifty years. Much of this decline is due to improvements in machine design. All modern machines feature individual enclosed motors and drives, and are provided with suitable guards at all danger spots. But, perhaps the most important factor in this picture is the improved training facilities and procedures which make the tradesman better able to analyze his job, recognize the danger spots, and take the necessary precautions before starting to work (1964, p. 57).

Although changes in the welding techniques and equipment within the last few years have placed more stress on student knowledge of safety procedures, these attitudes must also be internalized through an effective sequential learning process. A. D. Cunningham, writing in the Occupation Hazards Magazine, states:

> Steel industry safety specialists like their colleagues in many other industries, have been troubled by a slowly rising accident frequency rate (1969, p. 91).

Therefore, if we are training our vocational students for the world of work which would be predominantly industry, then as educators we must make such students more safety conscious. Safety as a primary content material for a welding theory handbook would no doubt have the support of students, parents, teachers and safety councils.

Cunningham also mentions:

> The National Safety Council shows a rate increase for industries, over a period of two years, climbing from a 6.33 to a 7.22 with indications that the frequency rate will continue to increase unless precautions are developed (1969, p. 98).

Sequential organization of safety material content seems to be supported by the Liberty Mutual Loss Prevention Services, in an article condensed from Young People in Industry which stresses:

> The importance of information and instruction available to the young worker to assure he understands each new step and hazard as he goes along (1970, pp. 16-20).

H. Mayfield in an address "The Importance of Safety in a Training Program" given at a convention of the American Management Supervisors states:

> The finest compliment that a community can pay a company is to say that it is deeply concerned about the safety of its employees (1971).

This statement by Mayfield is an indication of the importance of reviewing welding theory materials currently in use at schools and colleges where the primary purpose is training youth for the world of work. Industry in some

areas is endeavoring to make their employees safety conscious. This is supported by Eleanor Sims who states:

> Skill-training programs begin with a basic two-week course of general knowledge which includes all the processes and safety requirements in order to produce productivity, accompanied by high quality results (1970, pp. 34-36).

Time Allocation for Theory Segments

Many types of vocational instructional texts have been published with suggested maximum time periods allocated to various segments for teaching purposes. Instructors often take a negative approach to such time allocations since the learning abilities of the students are so diversified that time allocations become impractical.

Klausmeier, writing on "Learning and Human Abilities" states:

> At the same time the teacher is daily faced with the problem of deciding how large or comprehensive a unit of learning to attempt in order for students to acquire something that can be carried through to the next day or week (1961, p. 371).

W. B. Dockrell presents information similar to Klausmeier's when writing on "Organizing Pupils for Learning." In his writings he states:

> One of the perennial concerns of the educational psychologist has been the need to provide for individual differences among pupils. Yet the cynic might argue that one of the major purposes of education is the eradication of individual differences (1965, p. 21).

D. A. MacKay, in an article "Some Critical Issues in Education," presents the following viewpoint on time allowed for learning:

> The reliance which school organizers have traditionally

placed on definite periods of time for particular learning tasks is seriously questioned by Bloom. He argues that each student should be allowed the amount of time he needs to complete each learning task. A strategy for mastery must include some way of organizing schools so as to provide different amounts of time for different pupils (1968, p. 68).

Rossi apparently voices the opinion of the majority of welding instructors in vocational schools when writing on welding he states:

That the question of time allocation for a specific course is a difficult problem with which the instructor is faced at all times and which becomes especially critical when the course is limited to relatively few hours (1954, p. 23).

Summary Statements

The following observations selected from researched information indicates why an attempt should be made to supply a format for material which is effective for both teacher and student.

A. D. Cunningham states:

Instruction materials will be selected and developed to insure adequate levels of difficulty, high interest, and relevance of content and appearance to provide the unemployed with vocational and on-the-job training that would enable them to function successfully as regular employees of industry and business (1969, pp. 91-98).

Rouche and Herrscher further supports such a stand when he mentions:

That where institutions will be adopting a philosophy of educational opportunity for all--all abilities, all social and economic classes, all interests, and all ages then content must be selected on the basis of its relevance to the needs of the student (1970, p. 26).

Most of the reports mentioned relate to material requisites for student success, all which are relevant to

all types of vocational programs. H. B. Carey, Director of the Hobart Welding Schools, however, sums up welding instruction by stating:

> That personnel in the welding trade needs "know-how" or information in order to select not only the proper equipment but to select the right procedures (1969, p. 14).

Summary

1. The aim of education is to assist Alberta youth in the search for maximum self-realization. This is possible if teaching methods and theoretical materials are directed so that students learn to accept and enjoy the challenge of inevitable change. Students gain skill and confidence in problem-solving approaches when their learning experiences are based on flexible methods which focus on adaptability to changing situations.

2. A review of available literature indicates the need for revision and/or modification to keep pace with current trends.

3. Involvement and participation of instructors is obtained through good communication techniques. Errors or obstacles in implementation may be avoided by prior consultation. Since the task of continuous revision is of herculean proportions sharing in revision and research at all levels could prove more efficient, comprehensive and rewarding.

4. Consensus of opinion appears to indicate that suitable sequential welding theory is unavailable and the need exists for more effective instructional material

designed in a flexible manner for ease in adaptation to current trends.

5. Authoritative sources have pointed out that sequential presentation of theory is a progressive method which reduces the planning task to a manageable size and applicable to all learning, and particularly suitable for welding theory.

6. Feedback from instructors and follow-up of students could be utilized in programs as a criteria for evaluating the relevance of existing or newer methods.

7. Sequential presentation of welding theory appears to be the method of choice where internalization of attitudes to safety measures is an integral and continuing factor.

Chapter 3

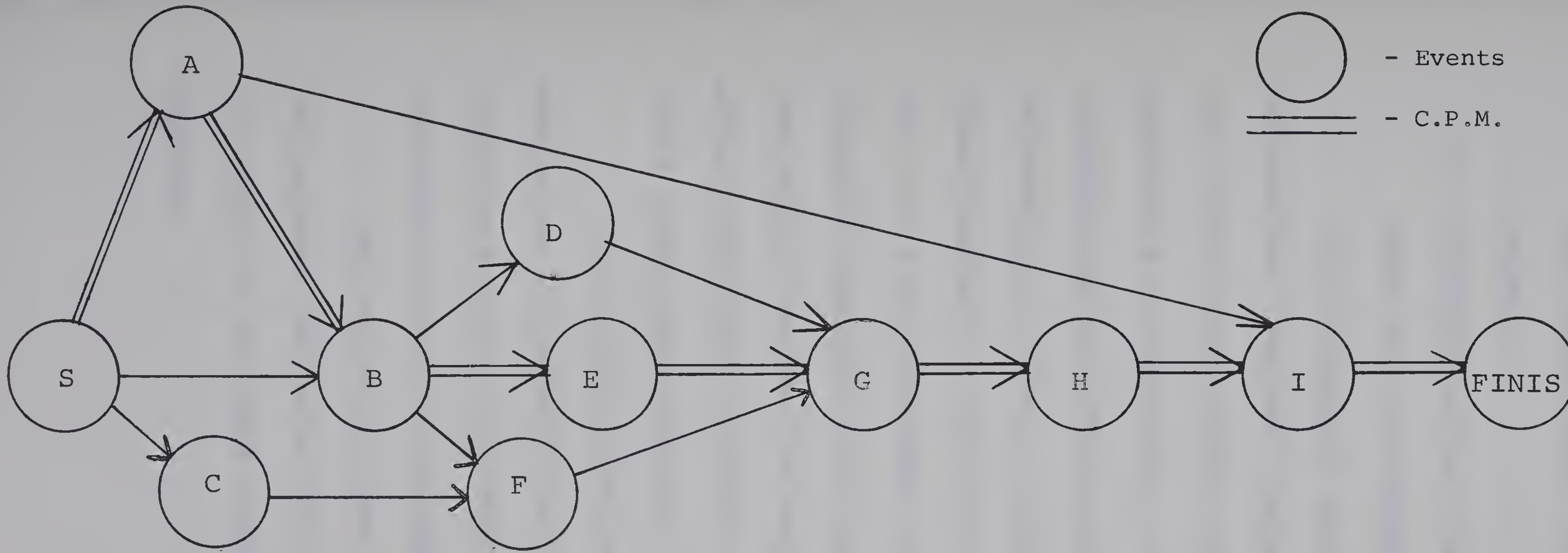
Methodology

Introduction

In order to justify the welding theory handbook development, it was considered necessary to use various surveys based on the PERT procedural design as shown on the following page. It was adjudged that the results of all the steps outlined in the PERT approach (prior to event "G") would have to indicate a total consensus before such a development could be considered justifiably valuable. The event "G" on the PERT procedural design, was determined as the indicator at which the results of the surveys would dictate continuation of the project.

The procedural principles, implemented to establish the need to continue with the project beyond event "G," was based on the results received and collated from:

1. A survey for sources of available welding materials.
2. A survey of theory material currently used in Alberta schools, and other educational institutions, in an area south of Calgary.
3. A survey to locate presently employed journeyman welders, certified through these same educational outlets.
4. Questionnaires compiled from surveyed information received from students presently enrolled in schools.



THE PROCEDURAL DESIGN

S . . . Starting Point
S-A . . . A survey for sources of available welding materials
S-B . . . A survey of present theory material used in Alberta Schools and other educational institutions in an area south of Calgary
S-C . . . A survey to locate presently employed journeyman welders certified through these same educational outlets
B-D . . . Questionnaires compiled from surveyed information (b) sent to students presently enrolled at (d)
B-E . . . Questionnaires compiled from surveyed information at (b) sent out to teachers (e) presently teaching welding in the educational areas mentioned
B-F . . . Questionnaires compiled from surveyed information (b) sent out to journeyman welders at their present location
G . . . Surveys analysed with results dictating whether to continue the project
H . . . An organized table of contents (preference of material and sequence of same dictated by the results of the total survey
A-I . . . Researched content material (screened as to new and obsolete) compiled and proofread at (I)
FINIS . . An approved welding theory handbook

5. Questionnaires compiled from surveyed information sent out to teachers presently teaching welding in the educational areas within the parameter of the study.

6. Questionnaires compiled from surveyed information sent out to journeyman welders presently employed.

The procedural principles implemented were based on information received through a personal interview pilot test carried out with eleven teachers other than those within the parameters of the study. The teachers contacted were graduate students who were taking summer session classes at the University of Alberta during the 1971 session. Eight of these teachers, although in the field of vocational education, had little or no direct contact with welding. Based on the comments received from these teachers, it was apparent that the lack of sequential subject material in many vocational areas indicated a need for research of subject material in areas other than welding.

To further substantiate whether a meaningful research should be initiated, the investigator arranged personal interviews with nine experienced welding instructors presently teaching within the geographical parameters of the study.

The major portion of information received from these two sources indicated that further investigation was warranted in regard to the type of material and methods used in teaching welding.

Instrumentation

By means of correspondence a total of sixty-two suppliers of welding equipment and accessories, together with ferrous and non-ferrous metal manufacturers were contacted. Eighteen replies were received from metal manufacturers and forty-four welding equipment suppliers. Each respondent submitted a source of new and improved equipment and text book information.

Welding text books in current use, in addition to other welding pass-out information, was accumulated from a large southern Alberta vocational school, a community college, the Northern Alberta Institute of Technology and the Southern Alberta Institute of Technology.

In order to satisfy the requirements up to event "B" of the PERT procedural design, the welding instructional information received through the sources mentioned above was collated, examined, and indexed for future consideration.

Through the cooperation of the registrar's office in the community college, it was possible to obtain the campus addresses of eighty welding apprentices who had been enrolled in welding programs from the year 1966 to the present.

These welding apprentices had received either a one- or two-year certification requirement through the college program. The final or third year of the program leading to first-class journeyman certification, had to be completed either at the Southern Alberta Institute of Technology or the Northern Alberta Institute of Technology in order to obtain

Alberta provincial certification.

Before questionnaires could be sent to these journeyman classified welders, a search for their present location was implemented by mailing the following information form:

Dear:

I am interested in contacting welders with either a first or second class journeyman certification for the purpose of accumulating data, by means of a short answer type questionnaire, in order to evaluate present welding theory material used toward such certification.

If you have received either of the above mentioned certificates and are presently employed in the welding trade and wish to share your theory material experiences, please return the form below, and a questionnaire will be forwarded immediately.

Yours very truly,

G. A. Kennedy.

. . . .

Name . . . .

Present Address . . . .

Type of certification . . . . Number . . . .

. . . .
Signature

A questionnaire, as shown on the following page, was mailed to the sixteen journeyman welders presently employed. It was considered that this type of questionnaire, when compared to a similar one given to vocational students presently enrolled in welding would produce more significant results after interpretation to indicate whether the

Journeyman Welding Questionnaire

Your answers to the following questions will be instrumental in deciding whether a welding theory handbook of new and sequential material would be appropriate for welding instruction purposes. PLEASE ANSWER ALL QUESTIONS BY MEANS OF A "CHECK" IN THE APPROPRIATE SPACE UNDER EACH QUESTION.

	Yes	No	Others
1. Did you use a welding theory text during your:			
(a) Apprentice year one			
(b) Apprentice year two			
(c) Apprentice year three			
2. If you used a text, was it supplemented with other printed information in your:			
(a) Apprentice year one			
(b) Apprentice year two			
(c) Apprentice year three			
3. If you did not use a text did you use handouts or other printed information in your:			
(a) Apprentice year one			
(b) Apprentice year two			
(c) Apprentice year three			
4. Were you made aware of new techniques and processes by printed information in your:			
(a) Apprentice year one			
(b) Apprentice year two			
(c) Apprentice year three			
5. Would you have considered a text with each section covered by Questions and Answers (for review purposes) of value in your:			
(a) Apprentice year one			
(b) Apprentice year two			
(c) Apprentice year three			
6. Do you feel that the sequence of material used for theory purposes could have been improved on during your:			
(a) Apprentice year one			
(b) Apprentice year two			
(c) Apprentice year three			

COMMENTS ____

____

____

development in question, a welding theory handbook would be realistic.

Students in two southern Alberta schools, special welding students, agricultural students, and first-year apprentice welders in a community college, were asked to complete a questionnaire as outlined on the following page. Cooperation of teachers and/or instructors was requested and obtained. For the purpose of comparison, this questionnaire was similar in format to the one formulated for journeyman welders.

Twelve questionnaires, distributed in random order, were given to each of four representative welding classes. The classes consisted of:

(a) high school students in a vocational welding class

(b) agricultural welding students

(c) first and second year apprenticeship students

(d) special welding students as defined by the college.

In the event that results of the journeyman welders' and presently enrolled student welders' questionnaires indicated a need for the development of a welding theory handbook, it was considered necessary to identify the appropriate qualities and content. Techniques for accumulating materials to identify the elusive qualities, and designed to meet present and future requirements would be required.

It was for the above reason that a two-phase Delphi research method was implemented as a means of predicting:

1. If the need for trained welders will continue;

STUDENT QUESTIONNAIRE

Your answers to the following questions will be instrumental in deciding whether a welding theory handbook of new and sequential material would be appropriate for instruction purposes at this time.

PLEASE ANSWER ALL QUESTIONS BY MEANS OF A "CHECK" IN THE APPROPRIATE SPACE UNDER EACH QUESTION.

1. Are you considering welding as a possible trade?

   Yes______ No_______ Undecided_______

2. Do you use a text for "Theory" information?

   Yes______ No_______ Undecided_______

3. If you have a text--Do you find it adequate?

   Yes______ No_______ Undecided_______

4. Are safety procedures taught before doing practical welding?

   Yes______ No_______ Undecided_______

5. Are you informed of new techniques and processes?

   Yes______ No_______ Undecided_______

6. Would you prefer a text with each section covered by Questions and Answers for review purposes?

   Yes______ No_______ Undecided_______

7. Would you like to serve a welding apprenticeship?

   Yes______ No_______ Undecided_______

IF YOUR ANSWER TO QUESTION 3 WAS "NO" PLEASE COMMENT BELOW:

Comments____

____

____

____

2. If a need exists for inclusion of projections for the future in welding instructional information;

3. What new processes and techniques if any, can be expected in the area of welding.

The Phase I approach of the Delphi type research method was implemented for the purpose of obtaining future predictions for welding. It was adjudged that subjective, predictive comments from companies involved in welding would:

1. Present relevant information for a two phase type of supportive questionnaire.

2. Indicate what role the welding instructor should play in the future.

3. Suggest what impact future welding techniques would have on present instructional welding data.

To accomplish this goal, an open-end questionnaire (as shown on the following page) based on the Delphi research method of prediction was mailed with an accompanying letter (see Appendix A) to eighty-six welding supply companies. Forty-three of the sixty-two suppliers of material information contacted previously were included in this group and were selected according to the quality of information received, availability, and its relevance for prediction purposes.

Based on the comments received through the Phase I questionnaire, a new questionnaire was formulated and submitted with an accompanying letter (see Appendix A) to all of the original eighty-six material suppliers for further

QUESTIONNAIRE

During research I have found Futurologists submitting the following statements:

(a) "Gas welding and cutting as it is known today will become obsolete by the end of this decade."

From an address on Technological Change and Human Development . . . The International Industrial Conference, New York.

(b) "It is doubtful that Laser Welding will find utility for routine welding jobs that are adequately handled by some more conventional processes. However, there are a number of "unusual welding problems" and the Laser should provide the answer to many of them."

From an article Laser Welding, Adams, Anderson, Hardway and Pfluger . . . Massachusetts Institute of Technology.

(c) Manual welding will be completely replaced by fully automatic procedures as early as the year 2000.

Based on the above statements:

What various types of welding processes do you forsee in order to facilitate the repair and/or fabrication requirements in the future?

Please discuss these statements in relation to the product or products presently being manufactured or those products being considered for the future.

predictive information. Nineteen of the original eighty-six companies did not return Phase I comments, so it appeared necessary to mail the Phase II questionnaire, (which is shown on pages 37 and 38) with another letter (see Appendix A).

The interpretive results of the Delphi research and the accumulated theory welding material were used to formulate a tentative table of contents for a welding theory handbook. This was accomplished through the efforts of a committee consisting of three experienced individuals in welding and the teaching of welding whose services were requested by written communication (Appendix A). The individuals chosen to present this information were from:

(a) the office of the Apprenticeship Board in Southern Alberta;

(b) a shop superintendent of the Department of Public Works in Southern Alberta; and

(c) the manager of a machine and welding shop in Southern Alberta.

The questionnaire as shown on pages 39 and 40, which consisted of the proposed table of contents as outlined by the committee, was mailed to the nine instructors used in the original pilot test for their consideration and comments.

The suggestions received from the instructors through the returned questionnaires made it possible for the three-man committee to compile major and minor welding information into a table of contents.

Please return to:

G. A. Kennedy
Dept. of Industrial and Vocational Education
The University of Alberta
Edmonton 7, Alberta, Canada

PHASE 2 OF QUESTIONNAIRE

	COLUMN 1					COLUMN 2				COLUMN 3
	strongly agree	agree	neutral	disagrees	strongly disagree	up to 1975	up to 1985	up to 2000	later than 2000	Your Personal Comments
1. The gas welding process should continue in wide use until at least the year 2000.										
2. Many gas welding production applications should surrender to arc welding by the year 2000.										
3. Oxy-fuel gas torches will be replaced by fine wire gas shielded welding for much of the industrial thin gauge sheet metal welding by the year 2000.										
4. Gas cutting equipment should have a much higher growth rate than gas welding torches by the year 2000.										
5. For the relatively small one-of-a-kind assembly, the covered electrode in the hands of an experienced welder should still be the fastest and most efficient welding method by the year 2000.										
6. There should be an increased need for trained welders up to at least the year 2000.										
7. Coated electrodes will decline in relative use, to less than 50% filler metal by the year 2000 due to an increase in the use of continuous wire methods.										
8. The tonnage of stick electrodes for filler metal purposes should continue to increase at least up to the year 2000.										
9. MIG. and TIG. welding continue to show growth, with MIG. operations forging well into the lead, and should replace manual arc welding by the year 2000.										

	COLUMN 1					COLUMN 2				COLUMN 3
	strongly agree	agree	neutral	disagrees	strongly disagree	up to 1975	up to 1985	up to 2000	later than 2000	Your Personal Comments
10. Shielded Metal Arc (including MIG.) should show increased growth, prompted by improvements in power supplies, wire and gases by the year 2000.										
11. More than two-thirds of arc welding will be done by automatic and semi-automatic processes by the year 2000.										
12. Electric resistance welding (spot & seam) will be taken over by other welding methods by the year 2000.										
13. Slowness of the Gas Tungsten Arc (TIC.) process will encourage improvements and substitution of faster methods by the year 2000.										
14. Plasma arc should replace TIG. welding in most applications by the year 2000.										
15. The Laser process (with only 10 or 20 machines presently in use) should be considered as mainly experimental up to the year 2000.										
16. New developments in the electron beam, which are increasing the scope of out-of-vacuum welding, should tend to speed acceptance of this process by the year 2000.										

The attached list of MAJOR and MINOR content material, after due consideration, has been placed in the following sequence by a Committee selected on the basis of trade and teaching experience in the field of welding. Your agreement or disagreement with this sequence for the purpose of instructional material in a welding theory handbook would be beneficial in assessing, not only the need, but the type of material required for instruction purposes.

Please make your selection in the spaces provided

Committee Selection		Your Selection	
Major	Minor	Major	Minor
B.	7	___	___
	6		___
	8		___
	10		___
	9		___
C.	12	___	___
	11		___
	13		___
	14		___
	15		___
A.	1	___	___
	2		___
	3		___
	4		___
	5		___
D.	21	___	___
	24		___
	23		___
	22		___
	20		___
E.	16	___	___
	18		___
	17		___
	19		___

MAJOR CONTENT	MINOR CONTENT
A. Metallurgy	1. Iron
B. Safety	2. Steel
C. Type of Joints	3. Cast Iron
D. Welding Principles	4. Heat Treatment
E. Terms and Definitions	5. Ferrous
	6. Clothing
	7. Hazards
	8. Explosions
	9. Types of Fires
	10. Type of Rays
	11. Weld Positions
	12. Type of Welds
	13. Symbols
	14. Weld Defects
	15. Defect Causes
	16. Type of Machines
	17. Type of Voltage
	18. Electric Circuits
	19. Electrodes
	20. Hardsurfacing
	21. Currents
	22. Tensile Strength
	23. Penetration
	24. Type of Beads
	25. Penetration

The table of contents for handbook purposes was again presented in questionnaire form (as follows) for further comments and suggestions from the original nine welding instructors who were previously involved with the material content:

Instructors Questionnaire

The attached consist of FOUR SECTIONS of proposed Major and Minor content data.

Under COMMENTS at the bottom of each section, please indicate what changes, if any, you would prefer in sequence of the minor content.

The Major Content preference sequence can be indicated by a number in the space provided at the top of each section.

Section ____
no.

Major Content . . . Metallurgy and Metallography

Minor content:

Metallographic Tests
Metal Identification
Iron and Steel
Cast Iron
Common Alloying Elements
Heat Treatment
Welding Temperatures
Heat Transfer
Expansion and Contraction
Non Ferrous Alloys

COMMENTS:
____
____
____

Section _____
no.

Major Content . . . Type of Joints and Welds

Minor content:

Joint Preparations
Weld Positions
Terms
Symbols
Weld Defects
Cause of Defects

COMMENTS:

Section _____
no.

Major Content . . . Safety in Welding

Minor content:

Welding Hazards
Clothing
Eyes
Type of Lenses
Physical Hazards
Explosions
Miscellaneous Hazards
Ventilation Tips
Type of Fires
Type of Extinguishers

COMMENTS:

Section ____
no.

Major Content . . . Principles of Arc Welding

Minor content:

Carbon Arc
Metallic Arc
Shielded Arc
Atomic Hydrogen
Terms and Definitions
Circuits
Types of Voltage
Types of Power Sources
Basics of Welding
Welding Electrodes
Type of Wear
Hardsurfacing Structures
Pipe Welding Procedures
Repairs and Fabrications

COMMENTS:

____

____

____

Summary

Exploring the need for a welding theory handbook included various surveys based on the PERT procedural design. The point "G" on the PERT procedural design was determined as the indicator at which results of the surveys would dictate continuation of the project.

A personal interview pilot test carried out with eleven teachers other than those within the parameters of the proposed study indicated the lack of sequential subject material in many vocational areas including welding, and

that studies were needed in regard to a more effective type of subject material and methods used in teaching.

The same test carried out with nine experienced welding instructors within the parameters of the study revealed the same results.

Surveys, questionnaires, correspondence by mail, and personal interviews were implemented to establish the need to continue with the project beyond point "G," with procedural principles based on results received and collated from:

1. a survey for sources of available welding materials.
2. a survey for theory material in current use in educational institutions south of Calgary.
3. a survey to locate employed journeyman welders certified through these outlets.
4. questionnaires from students presently enrolled.
5. questionnaires from teachers and instructors within the parameters of the study.
6. questionnaires received from employed journeyman welders.

The instrumentation was based on the following procedures:

1. A survey of 62 suppliers of welding equipment and metal manufacturer's resulted in submissions of material and a source of new and improved equipment from every firm.
2. Welding text books and pass-out material in current use in the educational institutions within the parameters of the study were collated, examined and indexed.

3. Eighty welding apprentices who had completed one or two years certification requirements at a community college were contacted and questionnaires were mailed to them.

4. A questionnaire was mailed to sixteen employed journeyman welders.

5. Students in two southern Alberta high schools representing four representative welding classes were given questionnaires distributed in random order.

6. A two-phase Delphi research as a means of (a) obtaining future predictions for welding and (b) predicting the appropriate qualities and content of the handbook.

Results made it possible for further questionnaires to be formulated for opinions on the accumulated research from the groups involved within the parameters of the study. A table of contents for the handbook was formulated and material tentatively arranged on projections for the future of welding.

Chapter 4

Analysis of Data

The initial use of a supplier's directory for mailing purposes was instrumental in obtaining a representative source of available welding material.

All of the sixty-two suppliers (eighteen metal manufacturers and forty-four welding equipment companies) were requested by letter for current welding data. They submitted various types of information. The major portion of the information was in the form of catalogues, brochures and books.

From the information received, only the type of material found relevant to the welding trade was accumulated and indexed. This data was later sorted in order to compile separate sections of common subject information.

The next step, as outlined by the PERT procedural system, was a survey of theory material currently in use in Alberta schools and other educational institutions in an area south of Calgary, and within the parameters of the research area.

The theory subject matter made available by the three schools and one college contacted in personal interviews, made it difficult to establish whether any common theory existed for the purposes of teaching welding.

The theory format used by the college surveyed, was found to differ from the curriculum used in the schools.

This difference was probably due to the fact that the college offered courses to first and second year welding apprentices which the schools did not offer.

The welding subject information obtained from the Southern Alberta Institute of Technology and the Northern Alberta Institute of Technology indicated that both institutes were using compatible welding type theory materials for teaching purposes.

The community college teaching general welding students seemed to favor a flexible approach to subject material. The use of handouts which were compiled by instructors covered various welding topics with no set sequence. Agricultural students and first and second year welding apprentices enrolled at the college were found to be using a compiled theory material similar to that being used in the technical institutes.

The subject information collected from the above institutions was also sorted and compiled in separate sections of common data for later handbook sequential evaluation.

Of the original eighty students who completed either first or second year welding requirements at the college, only sixteen presently in the journeyman welding classification returned the form attached to the letter which was used to trace their present address. Of the sixteen holding journeyman welding certification, only nine still resided in the Province of Alberta. Of the nine returning the address search form, seven were now residents of the Province of

British Columbia, one was a resident of Manitoba, and the other was temporarily employed in the Province of Ontario.

Since only four had indicated that they were no longer in the trade, it could be assumed that a substantial percentage of the original welding apprentices were still actively engaged in the trade. Due to the mobility aspect of this vocation, it was difficult to locate the addresses of the remaining journeyman welders.

The results received through the questionnaire mailed to the sixteen journeyman welders presently employed are indicated in the following table.

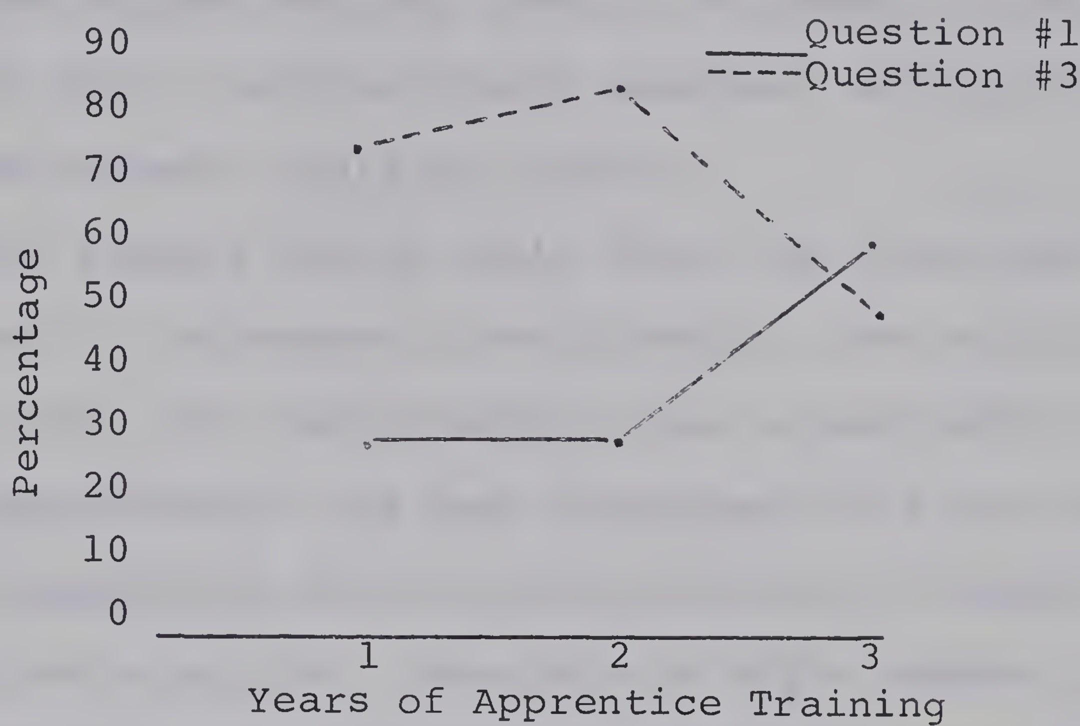
Results of Journeyman Questionnaire

Question 1		Question 2		Question 3	
Yes	No	Yes	No	Yes	No
3	9	3	1	9	3
3	9	3	1	10	2
7	5	5	4	6	6

Question 4		Question 5		Question 6	
Yes	No	Yes	No	Yes	No
7	5	9	3	10	2
9	3	9	3	7	5
10	2	10	2	2	10

As illustrated in the above table, returned questionnaires which were sent to the sixteen journeyman welders numbered twelve, or a seventy-five percent response. Although the sample was too small for conclusive results it did indicate that first and second year welders used text books less than

the third year apprentice welders, but utilized handouts and other printed information more frequently. This information is graphically shown in the following:



The results of the questionnaire indicated that approximately seventy-five percent of the welders taking first and second year welding apprenticeship training within the parameters of the study did not use a welding theory text. Apprentice welders taking their final year of training indicated that approximately fifty-eight percent used welding text books.

The results also indicated that other printed information supplemented text books, in most cases during the first and second year of the apprentice training period, but only about fifty percent of the time during the final year.

The analyzed data also indicated that approximately fifty-six percent of the first year apprentices were made aware of new techniques and processes, while as many as

seventy-five percent received some information on such areas during their second and final year of required school training.

The results of question five showed that seventy-five percent of the welders working towards journeyman classification agreed that a welding theory handbook, which included questions and answers, would be helpful.

Of the welders taking their third and final year of welding towards a journeyman classification, over sixty-two percent felt that the theory material was sequentially adequate. Approximately the same percentage of first and second year apprentices felt that the sequence of theory material was not adequate. From this we might assume that by the third year a sequential form of welding theory material would be beneficial to only about one-third of the students. Since sequential learning theory is designed for gradual progression to learn each step successfully, and stress on concepts leading to maximum generalization to other situations, it could be assumed that the first and second year apprentices felt that this had not in fact occurred.

Of the forty-eight student questionnaires issued, forty-eight replied; although in some question areas there appeared to be some hesitancy about giving a definite answer. The ambiguity of questions could be ruled out because each class was interviewed prior to filling out the questionnaire. The results obtained are shown in the table on the following page.

Results of Student Questionnaire

Question 1		Question 2		Question 3	
Yes	No	Yes	No	Yes	No
15	8	1	25	5	11
Undecided 25		At times 22		Partially 32	

Question 4		Question 5		Question 6	
Yes	No	Yes	No	Yes	No
25	1	13	3	19	6
Integrated 22		Sometimes 32		Undecided 23	

Results of the student questionnaire indicated that eighty-four percent of the students planned to continue further courses in this area and a handbook of theory would be helpful.

Fifty-two percent of the students indicated that they did not use a welding text book, and forty-five percent indicated that only at times did they use a welding text book. Moreover, the results of question three indicated that approximately eleven percent of the students felt the texts presently being used were inadequate. Since this percentage represented about one-quarter of those students using welding texts, it appeared to indicate that present welding theory material was not considered adequate for student purposes.

Safety, an important subject area as mentioned in the related literature, appeared to be adequately covered since ninety-nine percent of the students indicated in

question four that this was either taught before or integrated with the practical aspect of welding.

Question five indicated that only about six percent of the students were not informed of new techniques and processes. Only about twelve percent of the students took a negative attitude towards a handbook including questions and answers as indicated in question six.

Phase I of the Delphi type questionnaire resulted in a net return of seventy-eight percent or a return of sixty-seven of the eighty-six open end questionnaires forwarded to the previously mentioned material information supply group.

Of sixty-seven returns, only three felt that they were not qualified to give an answer for prediction purposes on such a technical subject.

The comments received with regard to (a) of the Phase I Delphi questionnaire indicated without a doubt that gas welding has for all practical purposes, been already eliminated in the large metal fabricators, but is still used and will be used in the next ten years for small repair work.

The indications from the comments received with regard to (b) of the same questionnaire was that laser welding and electron beam welding will continue to be limited to very specialized applications.

All companies commenting on statement (c) indicated that welding wires will increase up to the year 1980 with a

very slight drop off of stick electrodes.

In analyzing the comments with regard to the three statements in the Phase I questionnaire, it appeared that arc welding would eventually take over all oxy-acetylene welding procedures, and since welding wires are both manually and automatically applied, welders would be required in the future.

Phase II of the Delphi survey method consisted of a questionnaire developed from information compiled from the Phase I comments. Of the eighty-six questionnaires mailed, a net return of eighty-four percent or a return of seventy-two questionnaires were received.

Three companies who felt they were not qualified to comment on the statements on Phase I, together with the nineteen who did not reply, were included in the eighty-six companies sent a Phase II questionnaire. Of the twenty-two companies, only six returned completed Phase II questionnaires.

The results of Phase II are shown in Table 1. The positive outcome of question six, as well as question ten, as shown in table 1 was a definite indicator of a need for continuing to train welders for the future.

Fifty-four of the seventy-two agreed that there would be an increased need for trained welders up to at least the year 2000. Sixty-two of seventy-one agreed that shielded arc, a manual and semi-manual welding process would show an increased growth by the year 2000.

The poor response to the second column of the

Table 1

Results of Phase II of Delphi Technique

Item No.	Number of Responses ++	+	0	−	−−	Total	Score	Index	Probable Outcome	Total Expecting Outcome
1	9	36	0	9	9	72	27	37.5		
2	18	27	0	18	8	71	29	40.8		
3	16	20	18	18	0	72	34	47.2		
4	18	18	22	14	0	72	40	55.5	+	36
5	18	9	17	9	18	71	0			
6	36	18	11	7	0	72	83	115.2	+	54
7	27	20	16	8	0	71	66	92.9	+	47
8	0	10	18	36	8	72	-42	-58.3	-	44
9	14	18	31	7	0	70	39	55.7	+	32
10	45	17	9	0	0	71	107	150.7	+	62
11	27	24	14	7	0	72	71	98.6	+	51
12	6	11	27	9	18	71	-22	-30.9		
13	19	26	19	8	0	72	56	77.7	+	45
14	11	30	24	7	0	72	45	62.5	+	41
15	9	14	21	27	0	71	5	7.0		
16	9	45	18	0	0	72	63	87.5	+	54

Key to Score, Index and "Outcome"

1. For the score count the +/- entries as follows:

   ++ = +2
   + = +1
   0 = 0
   - = -1
   -- = -2

2. The index is the average score.

3. The outcome if + if index $\geq .5$ and - if index $\leq -.5$

Phase II questionnaire was an indication that many companies had accumulated only predictable information pertaining to welding, for a period up to approximately 1985.

Of the thirty-two companies who indicated a time factor for column two, the majority appeared hesitant to extend the prediction dates beyond 1985.

The questionnaire sent to the nine instructors covering major and minor headings, were all returned, with emphasis placed on safety in six of the nine returns. Metallurgy, followed by Types of Joints, for purposes of major heading sequence, following the section on safety was also indicated. Eight of the nine instructors indicated that Terms and Definitions should be considered near the end of a theory book.

The completed proposed table of contents sent to these same nine instructors in the form of a questionnaire were all returned. The results indicated a consensus of opinion with the suggested type of theory material and the major material sequential format.

The indicated differences were primarily in the sequential minor heading area, and were so limited as to be considered of little consequence for learning purposes.

Summary

Information on welding data was supplied by eighteen metal manufacturers and forty-four welding equipment companies.

Relevant material was selected, indexed, sorted and compiled into segments according to content.

Survey of theory material currently in use in Alberta schools within the parameters of the study carried out by the PERT procedural system and compiled.

Results:

(a) difficult to establish whether any common theory existed from material obtained.

(b) theory in college different since college offered courses in first and second year welding which was not the case in the schools.

(c) both the Northern and Southern Institutes of Technology were using similar welding theory materials.

(d) the Community College favored a flexible approach to subject material and used handouts compiled by instructors with no particular sequence for general welding students. The first and second year welding apprentices used compiled theory similar to that used by technical institutes. This was also true of the agricultural students.

(e) a substantial percentage of the original eighty students who completed either first or second year welding requirements at the college were assumed to be still actively engaged with nine still residing in Alberta. Difficulties were encountered as follow-up of students was not carried out in all areas.

(f) the results of the questionnaire mailed to

journeyman welders indicated that seventy-five percent of the welders taking first and second year welding apprenticeship training used hand-outs and reference material rather than texts, whereas fifty-eight percent used texts in their final year about fifty percent of the time.

(g) the analyzed data indicated that approximately fifty-six percent of the first year apprentices were made aware of new techniques and processes and seventy-five percent received this information during their second and final year.

(h) seventy-five percent of the welders working toward journeyman classification agreed that a welding theory handbook which included questions and answers would be helpful.

(i) sixty-two percent of the first and second year apprentices felt that the theory was sequentially inadequate whereas the third year students did not.

(j) the results of the student questionnaire indicated that one-quarter of the students using texts felt the material was inadequate. Ninety-nine percent indicated that safety as a subject area was adequately covered. Six percent of the students indicated that they were not informed of new techniques and processes. Eighty-eight percent of the students indicated that the

question and answer content would be helpful.

The results of Phase II from metal manufacturers and welding equipment suppliers are tabled. They indicated a definite need for training welders for the future and that the shielded arc welding would show an increased growth by the year 2000.

The questionnaires sent to nine instructors gave results closely approximating a consensus, differences in sequential placing of minor content was the area of slight divergence.

Chapter 5

Summary, Conclusions, and Implications

Summary

The purpose of this study was initiated in order to present a welding theory handbook of preferential and sequential data if and when information accumulated by means of a PERT procedural design indicated such a need and based on the following surveys:

1. By means of the Delphi technique, predictions for the future of the welding trade were accumulated through the expertise of industry, in order to formulate an opinion as to new and obsolete subject data presently being used.
2. The amount of new data available from the numerous welding supply companies was investigated for student and teacher resource material.
3. The type of text book information presently being used in the schools and other educational institutions for welding was collated.
4. The opinions of journeyman and student welders, in terms of the type and suitability of theory material presently being used for welding, in addition to suggested improvements were assessed and tabulated.
5. The opinions of experienced welding teachers in regard to sequential and preferential format and the contents of a learning theory welding book were analyzed.

The results from these surveys were considered

necessary in order to answer the following questions which would ultimately fulfill all of the objectives.

1. Would a welding handbook of acceptable and sequential material be an asset to vocational and/or industrial instructors and students in the schools or other institutions?

2. What type of welding information would be most helpful in a welding theory handbook in order to accommodate the needs of the welding teachers and students in the Alberta educational system?

3. Where, and by what means should presently acceptable current data be obtained, in order to fulfill the purpose of such a handbook?

4. What implementation procedures would be necessary to facilitate the inclusion of:

    (a) additional new data in a handbook, if and when it becomes available.

    (b) an instructional time weighting factor for each section.

    (c) accumulated data in an accepted standardized form.

5. In what sequence would the theory material be most strategically placed for maximum benefit to student and teacher?

Detailed Conclusions

The findings from analysis of the data support the following conclusions:

(a) The results of Phase II of the Delphi survey indicated

a consensus of opinion that manual type welding would continue and increase at least into the early part of the next century.

This prediction was based on scored responses which were received on questions related to manual welding in the Phase II section of the questionnaire.

A positive reaction to the following questions supports this prediction:

1. Question 6 with a score of +54
2. Question 7 with a score of +47
3. Question 9 with a score of +32
4. Question 10 with a score of +62

(b) The accumulated welding theory information made available from cooperative industries, while indicating a trend towards semi and automatic technological welding equipment, still demonstrated an advantage for academically oriented personnel required to cope with the mechanized welding of the future.

(c) The Delphi technique established valid reasons why the inclusion of welding theory should continue as an integral part of the program and also indicated what information could be deleted at this point in time for welding theory handbook purposes. Question (b) of the Phase I questionnaire indicated that information covering the Laser process at this time would be premature. Moreover, comments on this same type questionnaire gave conclusive indications that welding by means of the oxy-acetylene process was fast becoming obsolete due to new techniques and procedures using micro-wire.

The amount of new data available on request from supply and equipment companies in brochure and booklet form was found to be practically non-existent in the various schools where subject matter was collected for survey purposes. This brochure and booklet type data, after being indexed and screened for relevant information, was found to consist mainly of new information covering many of the recent welding techniques and specifications. These would be valuable if utilized for training purposes. The need for preparing students to cope effectively with welding trends of the future could be facilitated by inclusion of these current materials.

The welding theory included in the survey is used in the schools and college within the parameter of the study at the present time and consists of text books, handouts, and other forms of printed material. Much of the information supplied to the students had been compiled by the instructors and in most cases was found to be basic. However, the material had not been revised within recent years. It appeared that much of the information, compiled without sequential consideration, had been handed down from instructor to instructor, and from one school to another.

(a) The opinions expressed by journeyman and student welders in regard to the type of theory material presently being used for welding, indicated a high percentage of agreement with the statement regarding the previous survey.

The indication as shown in question 1 (a) of the journeyman welding questionnaire was that approximately

seventy-five percent of the welders taking first and second year welding apprenticeship school type training within the parameters of the study, did not use a welding theory text. The same survey however, indicated that fifty-six percent of the apprentice welders taking their final year of school training, used text books. This apparently indicated that:

(a) First and second year apprentice welders, during their school training period, were being prepared from instructor-compiled information for the purpose of passing required tests based on common material.

(b) Of the welders answering this type of questionnaire, more than one-half of the total may have completed their final journeyman school requirements at the same institute.

(b) Question 2 of the questionnaire completed by welding students, other than those enrolled in the apprenticeship program, indicated a strong agreement with the apprentices questioned in regard to text book material. In answer to the above question, fifty-two percent of the students indicated that they did not use a text book for theory purposes, and forty-five percent indicated that only at times did they use a text book for learning purposes.

(c) From the results received on Question 2 of the journeyman questionnaire, it could be assumed that other printed information supplemented text books in the majority of cases during the first and second year of the apprentice

school training period.

Question 2(c) of the same questionnaire, however, indicated that only about fifty-five percent of the welders in their final school training period had text books supplemented by other types of printed information.

The comments received on the welding student questionnaire in regard to the type of information accessible when text books were not used or unavailable, appeared to show a parallel with the answers received to question 2 on the journeyman questionnaire.

(d) Question 4 of the apprenticeship questionnaire indicated that approximately fifty-six percent of the apprentices taking first year school type training were made aware of new techniques and processes. Seventy-five percent received some information during their second and/or final school term type training.

Welding students, other than apprentices, indicated in question 5 of their questionnaire that over ninety-three percent were informed to some extent on new techniques, processes and specifications.

From the above information it could be assumed that:

1. Welding theory texts presently available to the welding students are found less suitable for the type of course information being taught, than the information compiled and supplied by the instructors.
2. That the time allotted for school type training of first and second year apprentice welders was

insufficient to allow for other than the required course information for test purposes.

3. That student welders other than those serving apprenticeships, received basic as well as additional information on new techniques and processes since the time factor had no influence on the students' ability to pass apprenticeship type exams.

(e) Comments from both apprentice and regular student welders, in regard to suggested improvements were so diversified as to be of little value for handbook purposes. However, of the welders taking their third and final year of welding towards a journeyman classification, sixty-two percent felt that the theory material was sequentially adequate. Approximately the same percent of first and second year apprentices indicated that they felt the sequence of the theory material was not adequate.

The welding students other than apprentices, indicated in question 3 of their questionnaire that:

1. Most welding students would prefer to obtain information from a book consisting of preferential type material placed in a sequential learning form.

2. A sequential form of welding theory in handbook form would eliminate to some extent, individual instructors' handouts. Through a form of standardization, the welder would retain orientation to course content when moving from one training center to another.

(f) Welding students indicated considerable approval and

agreement with the inclusion of tests and subsequent answers as a method to retain and review subject matter. Question 5 of the apprenticeship questionnaire indicated that approximately seventy-five percent of the welders working towards a journeyman certification favored such an approach.

Question 6 of the student questionnaire indicated that eighty-seven percent of the students considered that a theory handbook including questions and answers would be valuable.

General Conclusions

From the accumulated data of the various surveys, it was concluded that the first question to be answered in the summary had been fulfilled in the affirmative and a welding theory handbook was developed (see Appendix B) as part of this research and formulated according to information based on the answers to the questions within the summary.

The type of information for handbook purposes was selected:

(1) from present criteria required by the Apprenticeship Board.

(2) by collating subject matter presently being used in the schools.

(3) by screening the indexed information obtained through booklets and brochures from various welding equipment and supply companies.

This material was subsequently screened and itemized by a committee of three, who were selected on the basis of

extensive experience in the field of welding. The initial itemized list was forwarded to welding instructors within the parameters of the study to obtain their opinions on the quality of the material selected, and the implications and ramifications for students and teachers.

Subsequent analysis of the teacher's evaluation of the information led to a search for the most effective method to obtain current data from reliable and authoritative sources in order to fulfill the requirements for the handbook. Communication by letter and questionnaire was initiated in selected areas, with the result that valuable information, as well as permission for use of subject information, specifications, and line drawings relating to teaching purposes was obtained from publishing houses and industry.

Selection of an inexpensive functional design for presentation of the handbook was made on consideration of these factors, in addition to simplicity, durability and portability. Implementation procedures to include the functional aspect, i.e., the addition of new data in the handbook as it became available, and deletion of the obsolete could be facilitated by means of a ring binder. Instructor's opinions were divided on the approach for including new and relevant information as well as the suggested time weighting factors arranged for each section.

When selection of the accumulated data was completed and approved it was placed in the learning sequence considered most appropriate by the selected committee and instructors.

It was then summarized by the author for presentation.

Implications and Recommendations

This handbook has been developed to meet the criteria (found practical through research) as outlined in the objectives of the study. It is anticipated that the sequential format will prove valuable to students and instructors within the field of welding, as the desire to promote maximum generalization to changing situations has been inherent in this research.

It is hoped that the results of this study will stimulate similar studies in areas other than welding in vocational education. Studies in other areas should be encouragred with involvement and participation at all levels and the focus on realistic preparation of the students for a continuously changing world of work.

All the specific objectives previously outlined, have been accomplished with the exception of:

(a) the time weighting factor on each section of the prescribed content material for course study purposes.

(b) the loose-leaf approach for up-dating material.

The time weighting factor was considered impractical by the instructors who were contacted for material content allocation. This was due to variations in the length of each welding course as it applied to different groups of students, considered for research purposes, within the parameters of the study. Their approach was no doubt influenced by Rossi (1954) as mentioned earlier.

The same instructors agreed that the present loose-leaf or ring binder method for up-dating material appeared adequate for the present, but recommended that other ways of including supplementary information should be considered.

Since the scope of this study limited the sample of journeymen, it is suggested that in further studies of welding or other fields a larger journeyman population would allow for greater feedback.

For purposes of a similar study where the volume of research is of considerable proportions, the researcher would also suggest that the selection committee of three, be increased to at least seven. This would facilitate the arrangement of data in an advantageous sequence.

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APPENDIX A

LETHBRIDGE COMMUNITY COLLEGE
LETHBRIDGE, ALBERTA

OFFICE OF
THE DIRECTOR OF
PERSONNEL

October 7, 1971.

Dear

By means of various types of research I intend to evaluate the welding theory material presently being used in school and colleges.

I would appreciate any brochures or other information which your company may publish which could be considered pertinent to the welding trade in order to up-date present welding theory material for vocational student teaching purposes, should the results of the research indicate such a need.

I am contemplating using pictures throughout the handbook. Would glossy prints of your equipment be available to me for this purpose.

Yours very truly,

G. A. Kennedy.

LETHBRIDGE COMMUNITY COLLEGE
LETHBRIDGE, ALBERTA

OFFICE OF
THE DIRECTOR OF
PERSONNEL

Dear Sirs:

I am endeavoring to project, by means of the Delphi technique, the course that welding will take in the future, and would appreciate the help of your advisory staff in answering the attached questionnaire.

The research is being conducted for the purpose of establishing the future theoretical and practical needs of the vocational students who are intending to pursue a career in welding.

The enclosed questionnaire has been sent to all of the major metal and welding equipment manufacturers.

After completion of the data received I will forward to each respondent a short procedural form for the purpose of collating answers.

I would hope that all interpretive material could be compiled no later than November 30, 1971 and would therefore appreciate your valued predictions at your earliest convenience.

Correspondence should be forwarded to: GA Kennedy; Department of Industrial and Vocational Education; The University of Alberta; Edmonton 7, Alberta, Canada.

Yours very truly,

GA Kennedy
Director

GAK/mo
enc. 1

LETHBRIDGE COMMUNITY COLLEGE
LETHBRIDGE, ALBERTA

OFFICE OF
THE DIRECTOR OF
PERSONNEL

December 15, 1971.

Dear

I am interested in obtaining some assistance to formulate a Table of Content for a "Welding Theory Handbook" should the information received through various types of questionnaires indicate a need for a form of sequential theory material for student teaching purposes.

Initial indications presented by the 1st. phase of a two phase delphi questionnaire technique and supported by personal interviews with a number of vocational teachers apparently substantiate the need for new instructional methods.

I would appreciate having you on a small committee to help formulate the desired sequence of content material, a great deal of which has been made available to me by welding supply and equipment companies.

I am sure that a small group, with extensive experience in the field of welding such as yourself, will make such an effort possible.

I wish to hold a meeting with the group sometime between December the 18th. and the 22nd., and should you decide to act on my behalf, I would appreciate hearing from you as to your preference of dates for such a meeting.

Yours very truly,

G. A. Kennedy.

LETHBRIDGE COMMUNITY COLLEGE
LETHBRIDGE, ALBERTA

OFFICE OF
THE DIRECTOR OF
PERSONNEL

January 5, 1972.

Dear

To help an appointed committee introduce a table of content for a welding theory handbook I would appreciate your opinion of their initial selection of both major and minor material. This form of introductory approach to completing a table of contents was chosen for the purpose of having instructors presently in the teaching field present their opinion based on experience.

The committee will base the table of content, which will be sent to you for your opinion, on information received by means of the attached questionnaire.

Your cooperation is appreciated.

Yours very truly,

G. A. Kennedy.

LETHBRIDGE COMMUNITY COLLEGE
LETHBRIDGE, ALBERTA

OFFICE OF
THE DIRECTOR OF
PERSONNEL

January 14, 1972.

Dear

I wish to thank you for completing the questionnaire sent to you on January 5th. From the information received through the questionnaire, I have with the help of the committee completed a tenative Table of Contents for a "Welding Theory Handbook" which I am forwarding to you for further comments.

Please feel free to re-arrange any minor or major content material by placing the preferred number in the column identified as "Disagree".

Your cooperation has been appreciated.

Yours very truly,

G. A. Kennedy.

LETHBRIDGE COMMUNITY COLLEGE
LETHBRIDGE, ALBERTA

OFFICE OF
THE DIRECTOR OF
PERSONNEL

January 24, 1972

Dear Sirs:

The enclosed questionnaire has been formulated from information received through the questionnaires sent out on November 9, 1971. The results received have been excellent and I wish to thank you and your organization for the time and effort they gave in order to make Phase 1 of the study such a success.

In order to finalize my findings I would appreciate your reactions to the predictions on the enclosed questionnaire, by marking your responses in the spaces provided.

I have alloted three columns for the purpose of facilitating the answering procedures and to conveniently evaluate the reaction of all respondents.

Column one for agreement or disagreement.
Column two for indicating the period when changes can be expected.
Column three for subjective opinions where column one or two appear inadequate.

I would appreciate receiving the completed questionnaire by February 14, 1972 if possible, and I am sure that your cooperative approach will be instrumental in upgrading the teaching materials for many student welders.

Yours very truly,

G.A. Kennedy
Director

enc.
GAK/mo

LETHBRIDGE COMMUNITY COLLEGE
LETHBRIDGE, ALBERTA

OFFICE OF
THE DIRECTOR OF
PERSONNEL

January 24, 1972.

Dear Mr.

I am enclosing the second phase of my "Delphi Research Project" on welding techniques and their future implications for your perusal and comments.

This second phase of the questionnaire was developed from collated comments of the phase 1 open end questionnaire which I received from various companies.

Although your phase 1 comments were not among those received I feel that your knowledge of the welding situation would enhance any research pertaining to long term welding plans. I would therefore appreciate any information you may add to my findings by completing the enclosed questionnaire.

Yours very truly,

G. A. Kennedy.
Director

GAK/mn
enc.

APPENDIX B

THEORY

WELDING

HANDBOOK

CONTENTS

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PREFACE AND ACKNOWLEDGMENTS

This handbook has been prepared with an aim of providing theoretical information in a meaningful sequence to facilitate the practical application necessary for student welders as they advance through the apprenticeship levels to that of journeyman.

An attempt has been made to familiarize the inexperienced welder with the various facets of a welding course prior to actual practical application, and at the same time make available for the welding instructor presentable course material for teaching purposes.

Having had the privilege of training and supervising welders, not only in the training school but in industry, it is apparent that a theoretical understanding is the prerequisite of good workmanship. This handbook is intended to provide basic information, not only for the student, but also for those practical qualified welders lacking the necessary understanding and principles so essential for promotion.

The handbook has been divided into sections to facilitate immediate location of information on any particular phase of welding. Questions have been arranged at the end of each section for student review purposes, and the answers to these questions are given at the end of the handbook.

The author of this book wishes to acknowledge, with thanks, the cooperation received from the various companies, groups, and individuals who have helped to make this handbook possible.

Special thanks go to the many authors and publishers who generously gave permission to quote or use materials and photos from their publications.

WELDING SHOP RULES AND REGULATIONS

(1) Safety equipment is available for your personal protection.

(2) Become acquainted with the type and location of all fire fighting equipment.

(3) Grinding, chipping or welding must be done only when the proper eye protective equipment is used.

(4) Should an accident occur report it immediately if possible. First aid kits are available and with proper use can give protection from minor cuts or burns.

(5) Do not operate any equipment until your knowledge of such equipment is adequate enough to avert accidents.

(6) Welding or tacking on steel tables or other equipment without permission should not be tolerated.

WELDING

SECTION I

SAFETY IN WELDING

A workman with pride in his workmanship not only considers his own safety but the safety of others. If knowledge and foresight were the basic requisites of all workmanship then most serious accidents could be avoided. It is well to remember before starting any project that "Accidents don't just happen," they are brought about by ignorance and carelessness.

A. WELDING HAZARDS

(1) Harmful or poisonous gases encountered in the welding of some metals.

(2) Explosions due to improper handling or operation of acetylene generators.

(3) Explosions due to improper handling of gases or equipment used in welding.

(4) Burns to the operator or fellow workers, through contact with flame, sparks, hot metal or hot slag.

(5) Injury to the eyes from harmful rays, metal particles, etc.

(6) Explosions within enclosed objects or vessels which have contained flammable materials and were not properly purged of flammables. Examples: Barrels, tanks, etc.

(7) Fire caused by flying sparks, slag and hot metal.

B. CLOTHING

A welder's clothing should be free at all times from oil and grease and should not be of an inflammable material. Inflammable clothing have not only caused painful burns, but have been the cause of fires created by unsuspected smouldering while hanging in lockers after the welder's shift has ended.

Denims and cotton drills are apparently the most popular clothing around the shops today, due no doubt to the fact that they are cheap and shed scattered sparks fairly well. Although they will smoulder, the welder has no worry of this type of material bursting into flame if they are kept free from oil and grease.

Tanned leather or asbestos is the best type of material, but the workman will find them somewhat expensive and quite hot and heavy as compared to denims and wool.

Wool clothing is preferred by some welders since excessive cleaning does not shorten the life of the material to the same extent as denims. Wool has the added feature of not being very flammable.

NOTE: The welder should:

(a) Protect the head .... wear a cap or other suitable headgear.

(b) Use a shrink proof gauntlet.

(c) Never wear pants with cuffs nor body clothing with open pockets.

(d) Wear boots rather than oxfords and keep them securely tied.

C. EYES

NOTE: Any injury to the eyes should be reported immediately.

Suitable goggles must be worn by operators to protect the eyes from flying particles when welding, chipping or grinding.

The eyes must be adequately protected not only from the rays when welding but also from the sparks and hot slag. A special lens to filter the harmful rays is available for the welding operator in various shades. The operator has a choice of filter suited to his type of vision which will absorb ultra-violet, infra-red as well as most of the visible light rays.

No one shade of filter or lens will suit all welding and cutting operations and the operator, therefore, must select a shade in the range where glare is eliminated and yet the work point under the arc or welding tip is clearly visible.

In welding and cutting the radiation falls into three classifications:

(1) Ultra-violet rays

(2) Visible light rays

(3) Infra-red rays

(1) Ultra-violet rays:

Strong ultra-violet rays are capable of causing severe inflammation similar to sunburn on both the eyes and surrounding membranes.

The face, arms, neck and other parts of the body should be kept covered when welding due to the

fact that the intensity of the ultra-violet ray from the welding machine can cause a burn to the skin in a very short time, if exposed.

(2) Visible light rays:

Intense visible light rays may cause eye strain and possibly temporary blindness.

(3) Infra-red rays:

Infra-red rays are thought to be capable of causing cumulative effects which may lead to cataracts or retina injuries. Infra-red rays are the most dangerous to the eye.

1. TYPE OF LENS SHADE FOR FILTERING RAYS

The selection of the proper lens is very important. The desired lens is one of the darkest shade which will show a clear outline of the work without eyestrain.

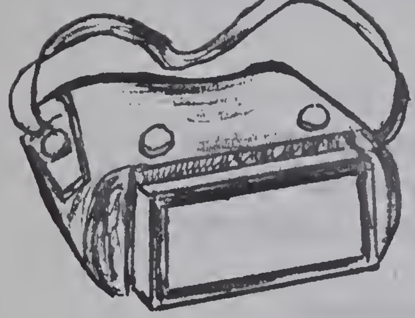
Recommendations have been established as to the shades of lens that should be used in various welding operations. These shades vary from No. 5 for light gas welding to No. 14 for arc welding or cutting. Lenses are available in green shades or amber shades, with green being the most popular. In arc welding the shade numbers work out much the same as for oxy-acetylene except that they must be considerably darker to filter out the higher intensity of rays. For example:

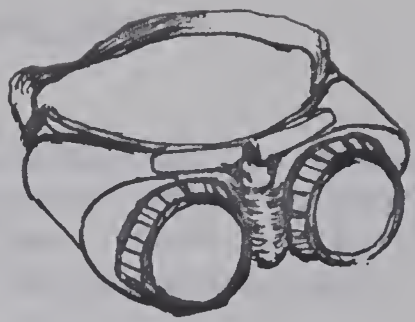
Shade # 8 & #9 - Sheet metal work.

Shade #10 - Medium arc welding.

Shade #11 - Heavy arc welding using electrodes

Shade #12 - of 3/16" and larger diameters.

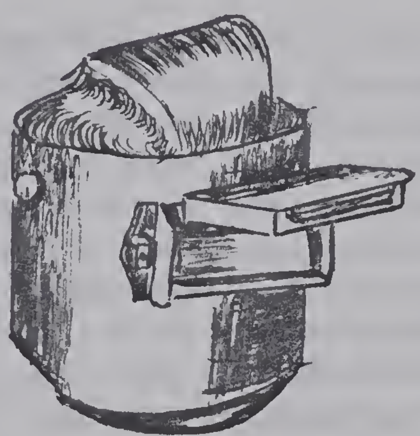




Oxy-acetylene Eye Protectors:

Lens Colors:

Amber	Aluminum Brazing.
Green	General Welding.
Cobalt-Blue	Brazing.
#4 or #5	Light Welding and Cutting.
#6	General Welding.
#8	Heavy Welding.



Electric Welding Eye Protectors:

#8 or #9	.....	Lens	.....	Light Shade.
#10	.....	Lens	.....	Regular.
#11	.....	Lens	.....	Dark.
#12	.....	Lens	.....	Extra Dark.

2. PROTECTING OTHERS FROM RAYS

It is important also that the operator have the same consideration for other people's eyes, that he has for his own. Don't strike the arc without warning when others are around.

Remember that reflected arc rays are very damaging to the eyes. When welding outside of the welding enclosure use fireproof portable screens to protect others from the effects of harmful rays.

De-slagging welds with undue precaution can cause blindness. Use a flipfront helmet for this purpose or other approved grinding shields or goggles.

3. INJURY FROM ULTRA-VIOLET RAY BURNS

Exposure to the ultra-violet ray can create deep and serious burns to the exposed skin of the welding operator. Burns of this type are extremely slow in healing and can leave scar tissue which continues to be sensitive not only to heat but to the cold. When we consider the temperature of the carbon arc which ranges from 6850 to 9550 degrees fahrenheit and compare this to the temperature given off by the rays of the sun, the operator is able to realize the danger from the welding ray exposure.

Mild ultra-violet ray burns should be treated immediately by the procedures listed in the First Aid Booklet. Many commercial drug products will be found to be adequate for minor exposure.

Major burns could be serious and medical attention and advice should be sought.

Arc Flash

Arc flash is a welding flash which causes the rays to come into contact with the unprotected eyes. This usually occurs in arc welding when the helmet is in the raised position and an arc is struck. If the flash is often enough or severe enough the eyeballs become covered with a myriad of small water blisters. The movement of the eyelids against the eyeballs cause irritation and pain. The eyes are also susceptible to bright light and will water profusely. In extreme cases, blindness will occur for a period of two or three days.

Temporary relief can be obtained by putting castor oil drops in the eyes. This lubrication effect will exclude the air and relieve the pain.

Compresses soaked in lukewarm tea will have a soothing effect.

After exposure to arc flash the welder would be well advised to wear dark glasses for several days.

D. PHYSICAL HAZARDS AND SAFETY PRECAUTIONS

(A) CONTACT BURNS

A burn is damage to tissue of the body resulting from the effects of extreme heat.

Burns resulting in injury from coming into contact with hot metal, flame, hot slag or sparks fall into two basic types:

(1) Superficial or surface burns.

Burns of the superficial type do not penetrate deeply and in general will heal up quickly. They are, how-

ever, painful and should receive first aid treatment. There are several products on the market which are suitable for this purpose. In minor burns only the outer layers of the skin are damaged; the burned area may be fiery red in color and may blister.

Treatment for Minor Burns

(1) In the case of minor burns and scalds where the skin is not broken, immersion of the affected part in cold water will often result in great relief from pain. Bearing in mind the danger of infection, careful washing in soap and water is excellent therapy.

(2) Keep patient comfortable.

(3) Offset chills by hot drinks and blankets.

(2) Deep Burns

Deep burns which penetrate beyond the skin and into the flesh are most often caused by metal at temperatures lower than red hot. This type of burn will take longer to heal, and care should be taken to prevent infection.

Major burns can be so deep as to destroy not only the skin but the underlying muscle and fat. The nerves may also be destroyed and any burn involving more than 50% of the body surface usually means death.

Treatment for Major Burns

On all serious burns requiring hospitalization only a dry sterile dressing should be used. Application of ungents, grease, etc. severely complicates medical treatment.

The burned area should be carefully covered, including the clothing where necessary, with band-

ages or sheeting to protect the area from infection. The injury should be handled as little as possible, and only with clean hands when handling is necessary.

NOTE: In the case of major burns:

(1) Avoid handling.

(2) Never use salves or lotions.

(3) Never remove burned clothing.

(4) Never break blisters.

(5) Cover all the affected areas with dry dressings.

(6) Use shock preventative treatment.

(7) Get medical help as soon as possible.

E. EXPLOSIONS WITHIN ENCLOSED OBJECTS OR VESSELS

Every year newspapers report either injury or death to workman due to vessels exploding. The most serious source of these accidents are the explosions in tanks containing gasoline or other volatile fuels. Accidents of this type, experienced by the welding trade, are usually due to failure of improper purging procedures before welding on tanks or various other fuel containers.

Gasoline as well as other light fuels give off highly volatile vapours which may accumulate in the weld seams of tanks or containers years after being void of liquid. The welder must be aware of the fact that during the cutting or welding process, the heat used will not only ignite these volatile vapours, but may generate enough heat to vapourize oils, greases, rubber, paint, tar and other materials; and make them potential killers.

REQUISITES OF AN EXPLOSION:

COMBUSTIBLES + OXYGEN + IGNITION

(a) The presence of explosive combustible gases.

(b) Some method of igniting combustible gases, commonly known as ignition.

(c) Oxygen or air which is necessary to support combustion.

NOTE: If any one of the above requisites are eliminated the welder is safe from the dangers of an explosion.

PROCEDURES IN RENDERING VESSELS AND CONTAINERS SAFE FOR WELDING

(1) Removal of all combustibles.

Purging by means of steaming or boiling in caustic solution. If such a method is continued over a prolonged period of time the trapped gases which have remained in the seams or open roots of welds will be eliminated.

This method is quite costly and does not lend itself to the large commercial jobs.

(2) Removal of all the air or oxygen.

This can be accomplished by the use of inert gas such as nitrogen, argon, or helium. The gas is injected into the vessel before welding, and is especially satisfactory in removing acetylene from manifolds before doing repair work.

All vents should be left open in the container to be purged, and should the air be heavier than the gas it will then be necessary to inject the inert gas into the top of the container. The purging gas would be delivered to the bottom

of the vessel if it is heavier than the air. Enough purging gas must be used to remove all the air.

(3) Displacement of air with water.

Should welding be necessary near the top of a large immovable vessel, or in any area on a small vessel, (one which can be readily manouvered in such a way as to place the required repair area upward or towards the top) then water placed in the vessel or container up to the cracked area would displace the air up to that point, and if the welder has some knowledge of purging procedures he can readily weld the vessel without difficulty or danger.

(4) Partial removal of combustibles and removal of the air by steaming.

Live steam blown in containers at low pressure is the most common accepted method of purging small vessels of combustibles. All vents should be open in the container and welding should be done while the vessel is hot and contains steam. If, after testing the newly steamed tank with an explosive meter, a positive test indicates further steaming, the tank should be allowed to first cool. It has been thought that static electricity in the steam due to purging a hot tank could create ignition which could cause an explosion.

NOTE: Further information on Welding or Cutting Containers can be found in the Oxy-Acetylene Handbook by the Union Carbide Corporation.

WELDING OF GAS TANKS

This is a topic that all welders should be well acquainted with if they wish to stay alive.

There are various ways of preparing gas tanks for welding but the methods are not only unsatisfactory but unsafe unless

the workman has a thorough understanding of the methods and a knowledge of the hazards involved.

Water Method:

As mentioned previously the use of water is limited to jobs where welding is high up on the vessel and where openings are such as to allow the air to escape freely. The volume of air space above the water must be small or the danger will still be present.

Carbon Monoxide Method:

This is a method whereby the welding operator attaches a hose from the exhaust of a truck or stationary engine and then places the hose in the vessel to be purged. The theory behind this method is that the carbon monoxide which is non-combustible will exclude all the air making the tank safe for welding.

In my twenty five years of experience I have never sanctioned this method for the following reasons:

(1) Should unburned gasoline enter the container with the carbon monoxide we have a further input of combustibles. For this reason an old motor could create a further hazard.

(2) Carbon monoxide should only be used outside. Breathing it can be fatal.

(3) Carbon Monoxide when mixed with air under the right conditions is an explosive compound.

Steaming Method:

When this method is used it will be first necessary to drain all flammable fluids from the container as steam will remove only the fumes. Remember that flammable materials when heated can give off explosive vapours. When steaming tanks or other vessels, we must have open manholes or vents in the upper part of these containers so that the steam entering

through the lower portion or bottom of the vessel can escape through the top portion carrying with them the explosive fumes. Use the same precautions as mentioned previously for the purging of vessels and stay alive.

SAFETY TIPS ON STEAMING

(1) Remove all fluids.

(2) Steam at least 1 hour for every 200 gallons of tank size; about 15 minutes on a 45 gallon drum.

(3) Always test after steaming with an explosive meter. (Note: Most natural gas employees keep a meter available.)

(4) Make a shield from behind which a lighted torch can be easily placed over and around the vents of freshly steamed gas tanks.

(5) Weld as soon after steaming as possible.

(6) Use low pressure steam.

(7) Should further welding become necessary after testing the finished job, allow the tank to cool, re-steam and follow the same procedures.

NOTE: Proper ventilation is an aid to the welder's purging method in that the moving air at a low velocity during welding does not permit any vapours formed by the welding heat to accumulate and become dangerously explosive. Circulating air discharges these mixtures through the open vents.

MISCELLANEOUS HAZARDS IN WELDING

FUMES

These are small particles of oxides produced when welding which can be alleviated to some extent by means of ventilation, larger work area and related conditions.

In welding the fumes are produced from the oxides of the parent metal, the electrode and the flux covering the rod or in oxy-acetylene welding the tinned flux used for lowering the melting temperatures of the oxides.

Iron Fumes:

The fumes from arc welding are usually not dangerous in normal concentrations since most welding operations take place on plain steels which produces the ferric oxides. The various fumes from plain steels can, however, become irritating and cause discomfort. Iron oxide in the lungs is known as "siderosis" but does not impair the function of the lungs. This condition can also occur in oxy-acetylene welding operators but is not nearly as common as with the electric welder.

Copper Fumes:

The oxides of copper are not considered toxic, but should welding of this metal take place in an enclosed area without ventilation, the welder could become ill and the symptoms, although usually vague, could be described as similar to the symptoms developed through close contact with zinc fumes.

Zinc Fumes:

Metal fume fever is attributed to the welding of galvanized metal in enclosed places without the proper type of ventilation. Usually we find there is no serious complications although the victim may experience an illness similar to stomach flu. The symptoms are headache, chills with a rise and fall in temperature over a period of as long as six to eight hours, and a tightness in the chest.

Lead Fumes:

All forms of lead are toxic with lead oxides the most

soluble in human tissue fluid. Melting, cutting or welding of lead could create a condition known as lead poisoning owing to the fact that the lead fumes, which if inhaled, enter the blood stream. Lead will accumulate not only in the various body organs but also in the bones, and does not lay there dormant, but may be set free to recirculate again. The symptoms of lead poisoning are lead line in the gums and a metallic taste in the mouth; as well as constipation, vomiting and nausea.

Manganese Fumes:

Poisoning due to the welding of Manganese and its alloys causes respiratory trouble and various changes in the nervous system of welders. This condition, however, is quite rare in welders, other than those operators in poorly ventilated manganese refineries.

Cadmium Fumes:

Cadmium plated or painted metals give off deadly fumes when heated, and care should be taken by the welder to ventilate the area in which this material is being welded. The welder should be aware of the fact that Cadmium and Galvanized materials are similar in appearance. Know the difference. Some materials are also coated with mercury and the fumes are also poisonous.

Aluminum Fumes:

The welder will experience no harmful effects from the welding of aluminum, titanium, chromium, nickel or vanadium.

VENTILATION TIPS

(1) Booths or Welding Screens should not hinder the movement of air for ventilation purposes.

(2) Welding on brass or bronze creates toxic fumes which should be eliminated through proper ventilation.

(3) Proper ventilation is necessary when welding on galvanized iron.

(4) Respirators should be used in enclosed areas where toxic fumes are prevalent.

(5) Air lines and fans can be used to eliminate fumes and toxic gases.

SUMMARY OF PROTECTIVE MEASURES

Safety Practices.

Use safety precautions in all your welding procedures. Be aware of the following hazards:

(a) welding near flammables.

(b) welding on vessels of an unknown content.

(c) welding on painted or coated materials.

(d) welding in unsafe positions.

Ventilation.

Adequate ventilation must be assured in most welding situations.

Fresh Air Supply.

In ill ventilated areas a fresh air supply should be used continuously when welding. Respirators should be used when doubtful, and all forms of safety equipment available

for immediate rescue purposes.

Goggles and Lenses.

Standards have been given for use in certain welding operations.

Protective Clothing.

Various types of clothing have been listed which are essential items for the welding operator.

Protective Screens.

When it is necessary for the welder to work in close quarters with other workmen, screens or protective partitions should be used so that radiation will not create a working hazard.

TYPES OF FIRES

Fires are categorized as three distinct classes depending on the fuel consumed and the procedures necessary to fight the fire which is consuming the materials.

In order to have a fire there must be a fuel, the temperature of which must be raised by heat in order for it to burn. As mentioned in the section on explosions, oxygen is necessary for combustion and so to have a fire air must be present or the fire will smother.

Therefore, the following three essentials, fuel, heat and air must be present to have a fire. Similarly to explosions, if we eliminate one of the three essentials for combustion there would be no chance of a fire; and where a fire is burning it is plain to see that by removing the easiest or most practical essential, the fire will be extinguished.

Decide on one of the following procedures in case of fire:

First: Cool the material to eliminate heat.

Second: Remove the fuel supply; which in most fires is not possible.

Third: Smother the fire to keep out the oxygen.

TYPES OF FIRES AND PROTECTIVE MEASURES

CLASS A ..... consists of wood, paper, clothing and similar materials.

Water is the most effective method of fighting Class A fires since it will penetrate and cool deep down.

On small fires of this type some extinguishers which do not contain water will be effective.

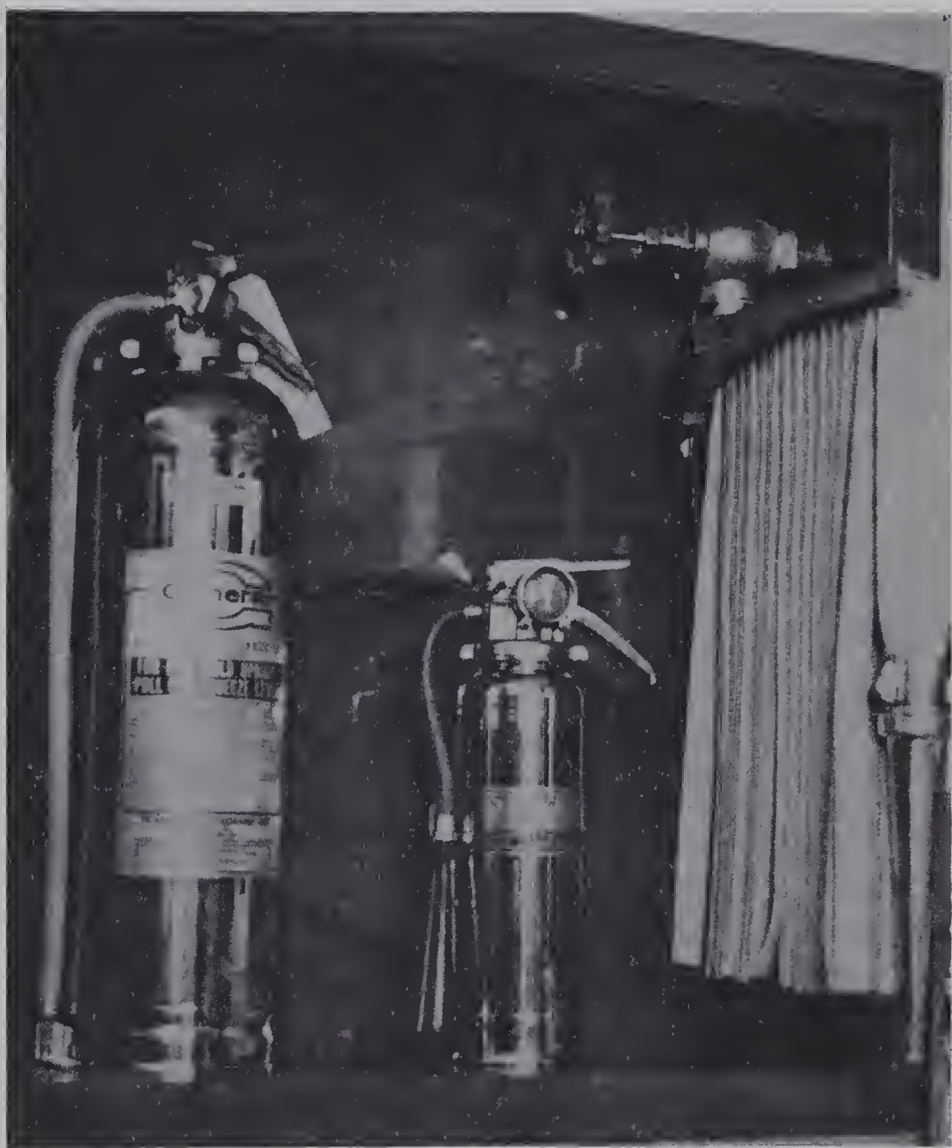
CLASS B ..... consists of oils, greases, paints and similar materials.

Once the flame is extinguished, which receives its fuel only from the vapour at the surface, the fire will go out. Foam, powder, sand and other types of non-flammable materials can be used effectively because of the smothering action.

Since most flammable liquids will float on water it is essential that water not be used on this type of fire. Water hitting this type of fire could throw the flames over a large area and perhaps create further problems.

CLASS C ..... consists of connected or live electrical equipment.

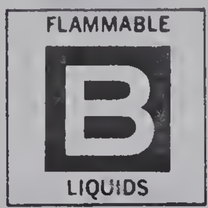
Non-conductive extinguishing materials with a smothering action should be used. Due to the added danger of electrical shock, water should never be used.



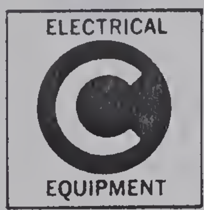
IDEAL FIRE EXTINGUISHERS FOR WELDING SHOPS

RECOMMENDED EXTINGUISHER "SUITABILITY" IDENTIFICATION

Triangle containing the letter "A" (green when shown in color)—identifies an extinguisher suitable for use on "Class A" fires—ordinary combustibles: wood, cloth, paper, rubber.



Square containing the letter "B" (red when shown in color)—identifies an extinguisher suitable for use on "Class B" fires—burning liquids: gasoline, oil, greases, paint, etc.



Circle containing the letter "C" (blue when shown in color)—identifies an extinguisher suitable for use on "Class C" fires—electrical fires: motors, switches, appliances, etc.

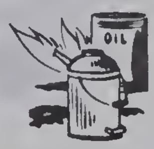
Five-pointed star containing the letter "D" (yellow when shown in color)—identifies an extinguisher suitable for use on "Class D" fires—combustible metals.

CLASS A FIRES

Ordinary combustibles: wood, cloth, paper, rubber.

Triangle containing the letter "A" identifies extinguisher approved for Class A fires.

CLASS B FIRES



Burning liquids: gasoline, oil, greases, paint, etc.

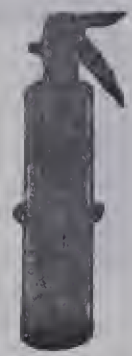
Square containing the letter "B" identifies extinguisher approved for Class B fires.

CLASS C FIRES

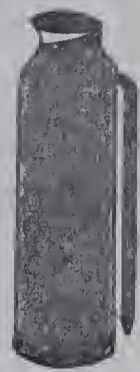
Electrical fires: motors, switches, appliances, etc.

Circle containing the letter "C" identifies extinguisher approved for Class C fires.

PORTABLE FIRE EXTINGUISHER SELECTION GUIDE

	DRY CHEMICAL			CO^2
SELECT THE CORRECT EXTINGUISHER FOR...				
	MULTI-PURPOSE	SODIUM BICARB.	PURPLE K	CARBON DIOXIDE
"A"	Yes	No	No	No
"B"	Yes	Yes	Yes	Yes
"C"	Yes	Yes	Yes	Yes
SPECIAL APPLICATION INFORMATION	Dry chemical extinguishers put out flammable liquid fires faster. Recommended for: oil and gas storage facilities, garages and service stations, industrial plants, trucks, busses, cars, and boats - wherever flammable liquids are used or stored.			CO_2 leaves no residue. Protects intricate & expensive electrical equipment. also recommended wherever food is handled.
HOW TO OPERATE	Squeeze handle. Sweep under flames.	Squeeze handle. Sweep under flames.	Squeeze handle. Sweep under flames.	Squeeze handle. Direct at base of flames.

	WET CHEMICAL			
				
	WATER		PUMP TANK	SODA ACID
	(Stored Pressure)	(Cartridge Operated)		
"A"	Yes	Yes	Yes	Yes
"B"	No	No	No	No
"C"	No	No	No	No
	Economical protection. Recommended for heated buildings, factories, office buildings, schools, churches and hospitals. Can be furnished for wall cabinet installation.			
	Squeeze handle. Soak burning material.	Invert. Bump. Soak burning material.	Hold hose and pump. Soak burning material.	Invert. Soak burning material.

<table>
<tr><td rowspan="3"></td><td colspan="3">WET CHEMICAL
  </td></tr>
<tr><td colspan="2">LOADED STREAM</td><td rowspan="2">FOAM</td></tr>
<tr><td>(Stored Pressure)</td><td>(Cartridge Operated)</td></tr>
<tr><td>"A"</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>"B"</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>"C"</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td></td><td colspan="2">An anti-freeze extinguisher with a chemical that tends to retard re-ignition in Class A fires. Ideal protection for unheated buildings. Underwriters' Laboratories-rated to fight Class B fires.</td><td>Practical & economical extinguisher for facilities requiring both Class A and B protection.</td></tr>
<tr><td></td><td>Squeeze handle. Soak burning material.</td><td>Invert. Bump. Soak burning material.</td><td>Invert. Blanket fuel surface.</td></tr>
</table>

QUESTIONS TO SECTION I

1. Name four (4) welding hazards which, if foreseen, should avert accidents.

2. What are three (3) types of materials which are classified as adequate for a welding operator's clothing?

3. What are the three (3) types of rays which concern operators when welding?

4. What color lens would be considered desirable for general oxy-acetylene welding?

5. Of the following numbered oxy-acetylene welding lenses which would be best suited for general welding; #4, #5, #6 or #8?

6. What is the comparison between the intensity of the sun and the ultra-violet ray?

7. Of the rays mentioned, name the one most likely to create cumulative effects which may lead to cataracts or retina injury.

8. Why is it sometimes necessary to use portable welding shields?

9. What precautions must be taken when using internal combustion engines inside buildings or in confined places?

10. What are the two (2) basic types of burns which all welders should be aware of?

11. When considering others, what should the welding operator do before placing hot iron in prominent places?

12. What welding term is used to describe eyes burned by ultra-violet rays?

13. When we steam a vessel which had contained explosive material, we use a single term known as?

14. What are the three (3) requisites of an explosion?

15. What two (2) reasons should be given for not wishing to purge a gas tank by means of engine exhaust fumes?

16. Why is resteaming of a warm vessel not a recommended procedure in purging?

17. What are the safety precautions recommended by responsible authorities before welding gas tanks?

18. What disease is contracted by the welding operator welding on zinc or zinc alloys in a non-ventilated area?

19. What do fires recognized as Class B type consist of?

20. What label do approved fire extinguishers carry?

WELDING

SECTION II

TYPE OF JOINTS AND WELDS

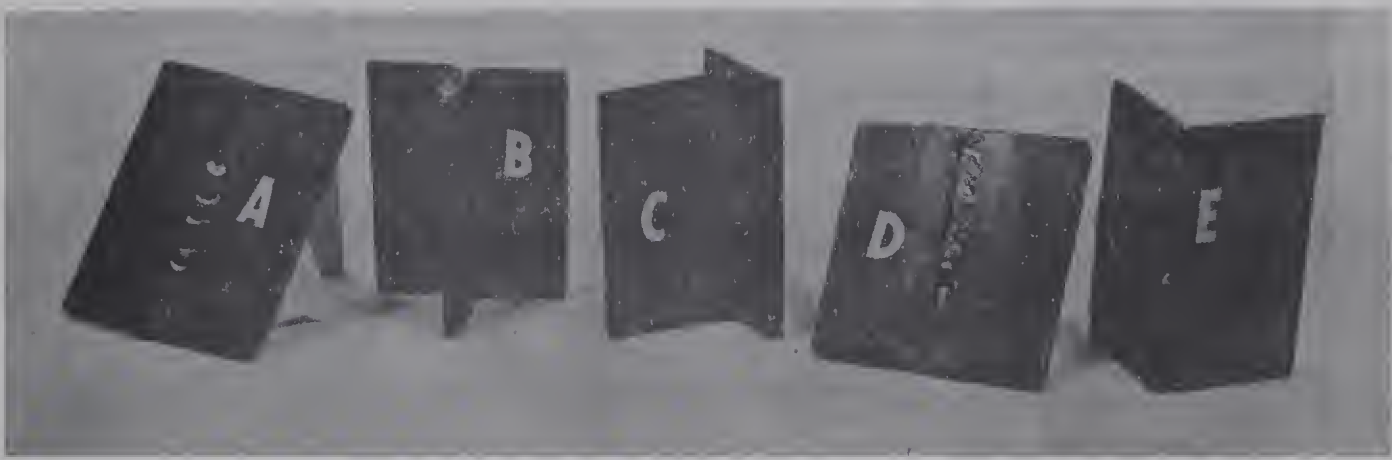
Welding is the process of uniting metallic parts by heating and allowing the metals to flow together, or by hammering or compressing after heating.

In arc welding heat is generated at the point of contact between the work to be welded and the electrode. The metal parts to be welded and the electrode fuse together in a finished weldment. In oxy-acetylene welding the high temperature at the tip makes melting of the parent metal possible, and with the addition of a welding rod fusion is completed.

Since it is necessary for the welder to prepare materials prior to welding, knowledge of the different joint styles and the basic named welds for these joints are essential.

For the purpose of this handbook welding joints will be described under the five common headings: Edge, Corner, Tee, Butt and Lap. Similarly the welds will be described as: Plug, Fillet and Groove.

The welder should become familiar with the following sketches which depict, not only the type of joints and welds but also the various types of preparation which make better welding procedures possible.



(a) Lap Joint (b) Edge Joint
(c) Tee Joint (d) Butt Joint
(e) Corner Joint

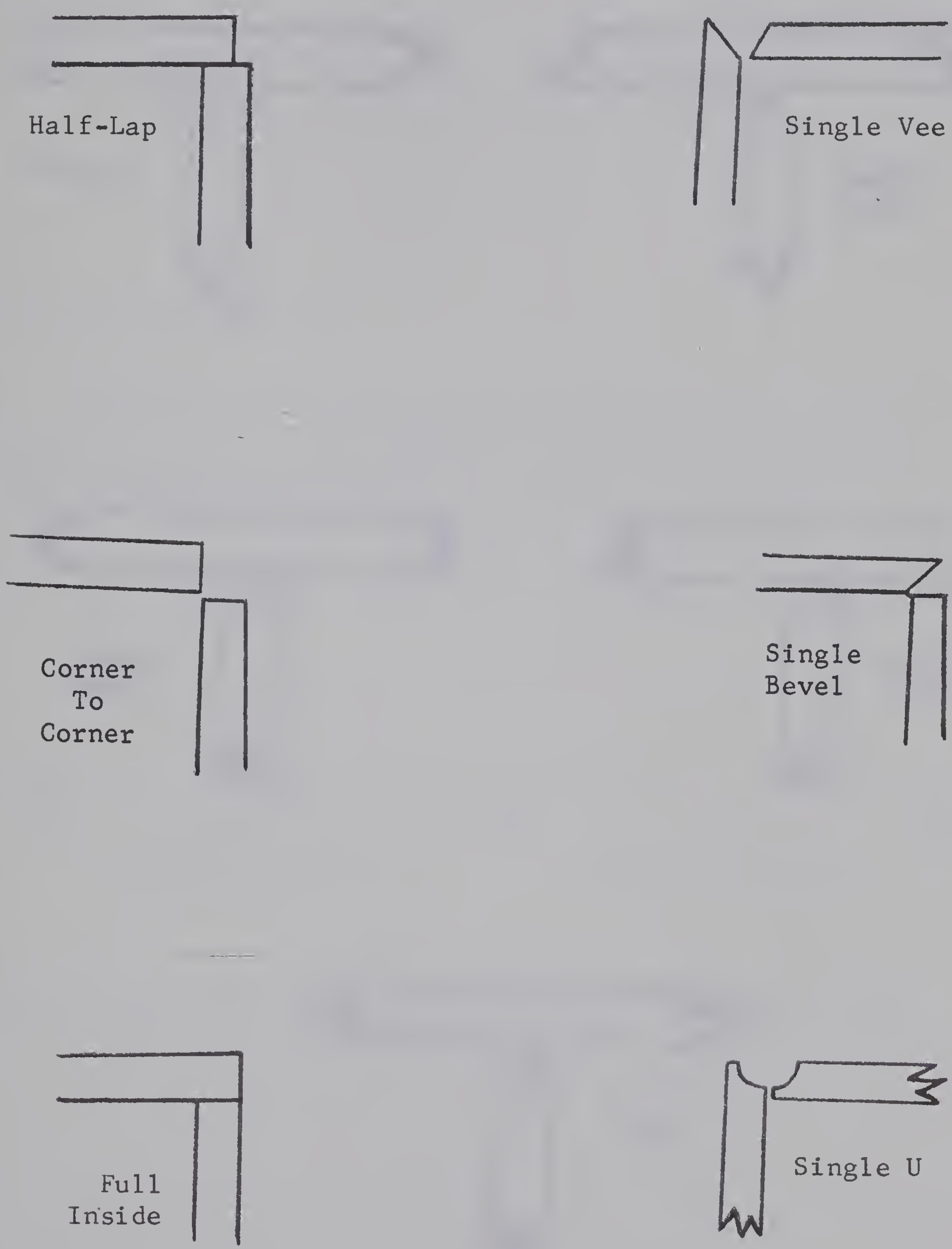
JOINTS AND WELDS

EDGE JOINTS

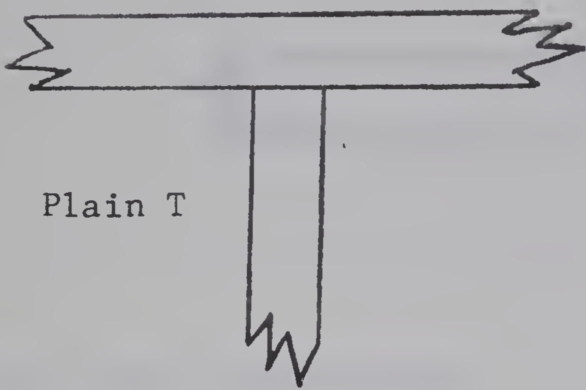
Flanged Edge Weld
Double Type

Flanged Edge Weld
Single Type

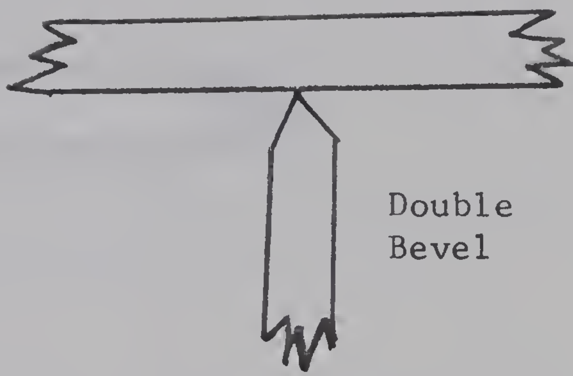
CORNER JOINT CORNER PREPARATION



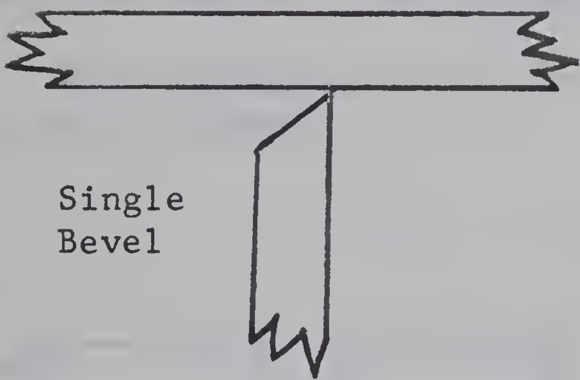
TEE JOINT AND TEE PREPARATIONS



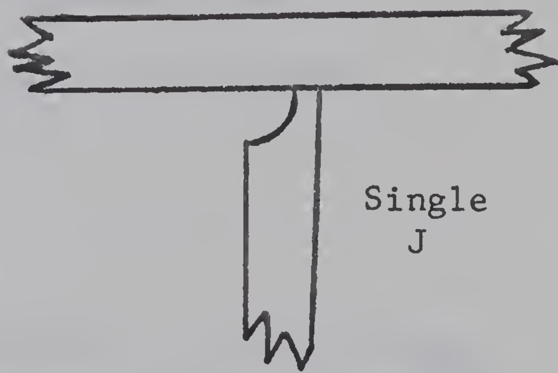
Plain T



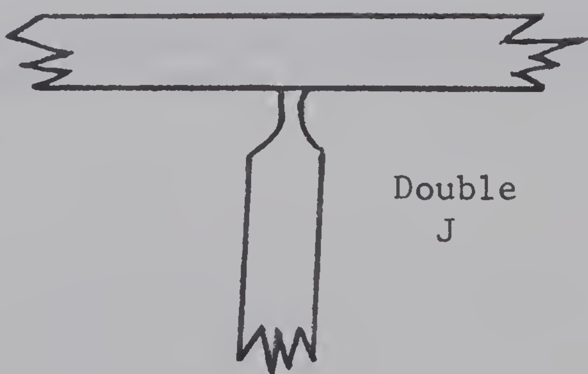
Double
Bevel



Single
Bevel

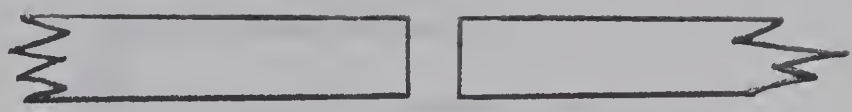


Single
J



Double
J

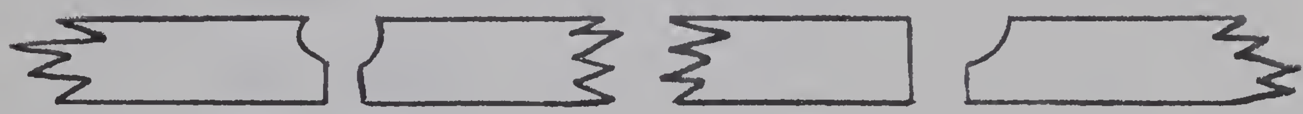
BUTT JOINT



BUTT JOINT PREPARATION

These joints can be prepared as above and are known as Square or Plain. If one piece of the above is beveled it will be known as a Bevel preparation, but if both pieces should be beveled it will then be a "V" preparation.

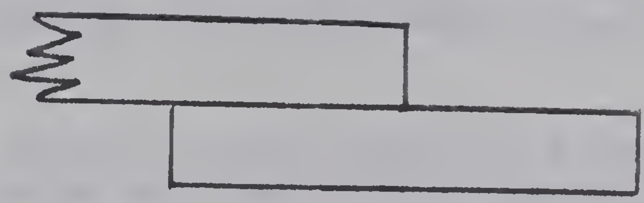
Other preparations of the Butt Joint as illustrated are not so common.



Single "U" Groove   Single "J" Groove

NOTE: When joints are prepared and welded from both sides they are classed as double joints or welds.

LAP JOINT



All the aforementioned weld joints are fused by one or more of the common weld types which are known as:

(1) Bead

(2) Weave

(3) Fillet

(4) Plug or Slot

(5) Groove

(a) Square

(b) "V"

(c) "U"

(d) "J"

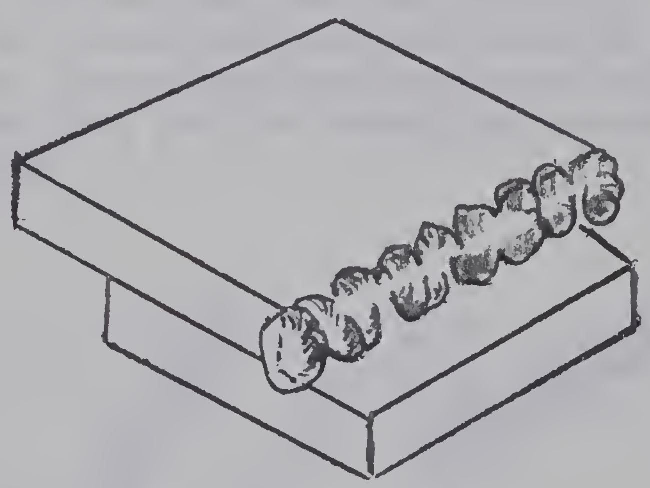
(e) Bevel

Bead welds are made without any side motion of the electrode and can be made without spacing or preparation. It is mainly used for building up worn surfaces.

Plug and Slot Welds take the place of rivets. Where two pieces of material have been lapped and fusion must not take place on the edges, a hole or slot is made in one of the pieces which is then placed over the other piece, and welding takes place through this opening fusing both pieces into one, leaving the outside edges intact.

Weave welding is the running of a bead, by means of the electrode, using side motion while proceeding on a given line. There are many variations of weave manipulations.

Fillet welds are used on Tee Joints, Lap Welds, and Corner Joints as illustrated.



Fillet Weld

Groove welds are filler welds for such preparation as "V", "J", "U" and edge joints found on various Butt and Corner Joints.

The following welds are used at times in conjunction with some or all of the preceding types of welds:

Intermittent Welds.

These are short welds of equal length spaced usually at equal intervals along a joint.

Continuous Welds.

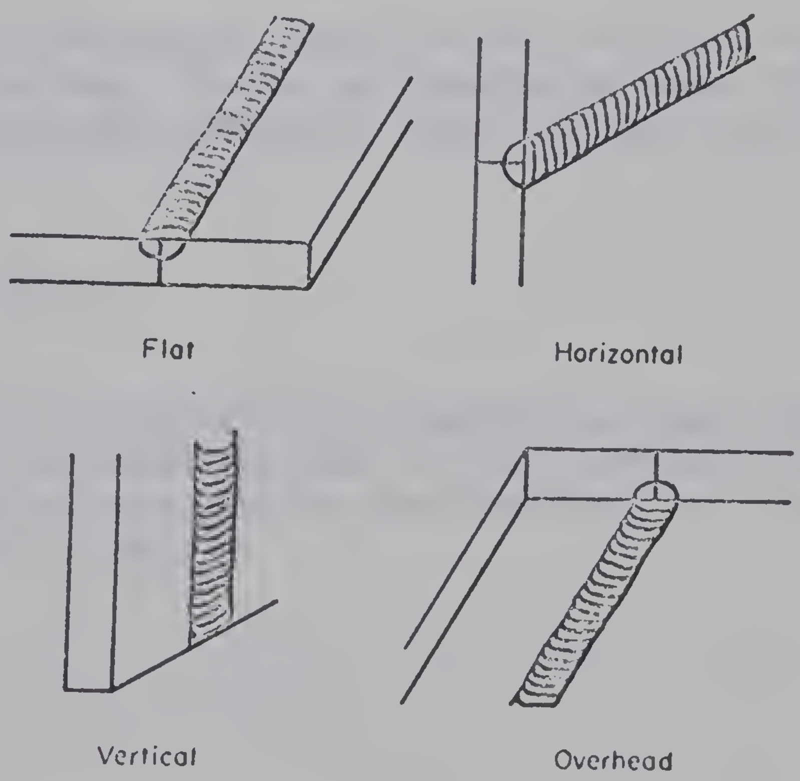
This is a continuous, unbroken weld throughout the entire joint.

Tack Weld.

These are short, small welds which are spaced at intervals to maintain alignment of a weldment.

WELD POSITIONS

There are four defined welding positions and it should be noted that all electrodes are not suitable for all positions. For this reason, the welding operator must become acquainted with the various rods and the techniques necessary to operate them successfully.



FLAT WELDING

Wherever possible, and especially in industry, welding should be completed in the Flat position as it is faster and cheaper. Jigs are used to facilitate the turning of weldments so that flat position welding becomes possible.

OVERHEAD WELDING

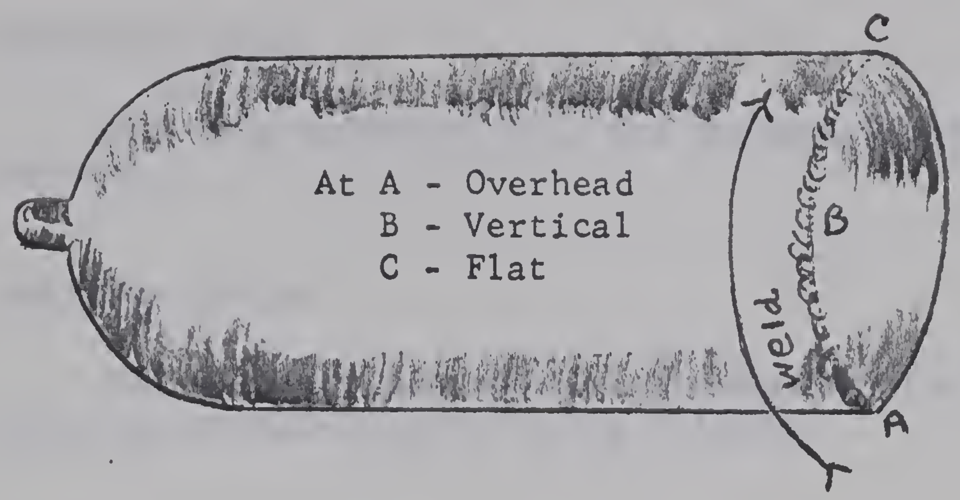
In this position the molten metal from the material and rod has a tendency to fall from the bead position. Arc current or flame temperature must never superheat the parent metal to an extent where it falls away due to the gravitational pull.

VERTICAL WELDING

Usually the welder completes all vertical welds from the bottom to the top. In the arc welding process, lighter materials can be welded downhand, (from the top to the bottom).

HORIZONTAL WELDING

Welding in this position creates the same problem as vertical and overhead welding in that experience and practice is necessary to overcome the gravitational pull exerted on the fluid molten metals.



Welding Positions

JOINT AND WELD TERMS

BEVEL

Edge preparation.

BEVEL ANGLE

The angle formed between the prepared edge of a piece of the parent metal and the plane perpendicular to the piece.

BLOWHOLE

Cavities formed during welding due to trapped flux or gas.

CASCADE SEQUENCE

A build up sequence wherein weld beads are deposited in overlapping layers.

CRATER

A depression at the termination of a weld bead.

DEPOSITED METAL

The metal added to fill the preparation during welding.

DEPTH OF FUSION

The distance that fusion extends into the base metal from the surface melted during welding.

FUSION

A joining together of the molten metals on the surface exposed for welding.

GROOVE ANGLE

The total included angle of the groove between parts to be joined by a groove weld.

HEAT-AFFECTED ZONE

That part of the parent metal which has a change in mechanical properties due to the heat from welding or cutting, but as yet has not reached the melted state.

INCOMPLETE FUSION

Fusion which is not complete for the purpose of full tensile strength.

JOINT PENETRATION

Fusion of metals through the joint preparation to the point where complete penetration has taken place on the underside of metal.

KERF

The channel or groove left by the removal of metal through the cutting process.

PARENT METAL

The base metal or the metal on which the preparation and weld will take place.

PEENING

A process of stress relieving by pounding the metal with a hammer.

POROSITY

The welded metal contains holes throughout due to gas pockets created by improper welding procedures.

RESIDUAL STRESS

This may also be known as locked-up stress which remains in a weldment as a result of mechanical and/or heat treatment.

ROOT FACE

That portion of the groove face which is adjacent to the root of the joint.

ROOT JOINT

Where the bottom of two beveled pieces meet when faced together for welding.

SLAG INCLUSION

Entrapped nonmetallic materials between the weld metal and base metal.

SPATTER

The metal particles which do not become a part of the weld bond but fly at random adhering to the parent metal.

TOE OF A WELD

The junction between the face of a weld and the base metal. An example would be the hypotenuse of a fillet weld.

UNDERCUT

An unfilled groove melted into the parent metal adjacent to the toe of the weld.

WELDMENT

An assembly of welded components.

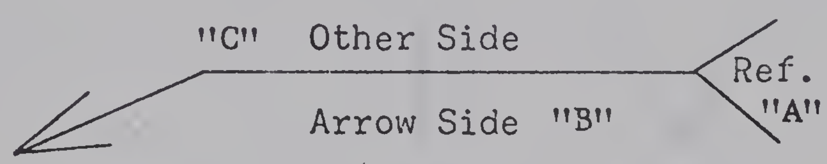
SYMBOLS

Without the use of welding symbols the draftsman would be unable to relay all pertinent information (related to the weldment) to the operator or job superintendent, other than by writing, which could create costly problems.

By means of standardized welding symbols complete information can be placed on drawings in a compact manner. Even though only a few symbols will be used in the majority of cases, the use of these symbols will eliminate the necessity of written explanations.

The joint will be the basis of reference, and the type and preparation of this joint as well as the type of weld will be indicated by a symbol having what is defined as the (1) arrow side, (2) the other side (the side opposite the arrow point) and (3) both the arrow side and the other side. These symbolic expressions will locate the weld with respect to the joint.

WELDING SYMBOL



Welding specifications, procedures, and other information to be used in making the weld is placed at "A" known as "the tail of the symbol".

Welding symbols will be placed above or below the reference line "B" depending on what side of the joint welding is required. When the various welding symbols are placed below the reference line the type of preparation or weld, as indicated by the symbol, takes place on the arrow side. When the symbol is placed above the reference line the welding takes place on the side of the joint opposite the arrow.

A break in a straight reference line denotes that preparation will be completed on that portion of the parent metal towards which the break is pointing, keeping in mind the preparation as being arrow side, opposite arrow side, or both.

A black dot at the break as represented at "C" would mean that welding can only be completed at the job site. A circle at point "C" means to weld completely around the project at the position as designated by the arrow.

The following illustrations represent the more common symbols, as well as dimensional information and other data.

ARC AND GAS WELD SYMBOLS

TYPE OF WELD SYMBOL

Groove

1. Square

2. "V"

3. Bevel

4. "J"

5. "U"

Bead

Bead (build up)

Fillet

Plug or Slot 

Whenever a symbol such as the Bevel, Fillet and "J" are placed on a reference line the vertical part of the symbol must always be drawn on the left.

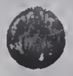
RIGHT WRONG

SUPPLEMENTARY SYMBOLS

Contours (1) Flush 

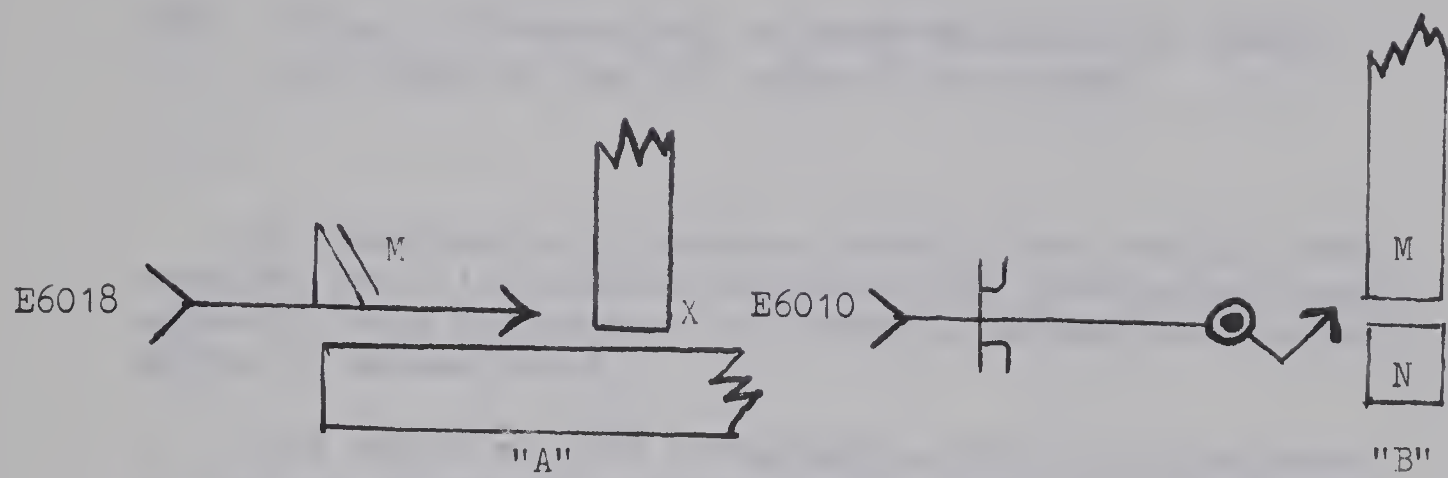
(2) Convex 

(3) Concave 

Field Weld 

Weld All Around 

WELDING SYMBOLS



We have illustrated the two forms of weld symbols in order to acquaint the student with the reason behind the straight arrow "A", and the broken reference line on the "B" illustrated arrow.

The TEE weld at "A" shows a FILLET weld symbol on the top of the reference line which denotes a fillet weld to be made on the other side opposite the arrow point, at "X". Further information is given at the tail of the arrow. The E6018 refers to the type of rod which will be used.

The Contour symbol on the FILLET weld denotes that the toe of the weld is to be machined flush.

All Contours listed on the Supplementary Symbols are formed by machining, chipping and grinding and are symbolized by the letters M, C or G placed over the contour symbol, and depending on the method preferred for a particular weldment.

The broken reference line arrow "B" denotes that preparation will take place on only one section of the weldment. Preparation as signified by the symbol on the reference line will take place only on that portion towards which the break

is made. Arrow "B" having a "J" preparation denoted on both the top and bottom of the reference line signifies the need for preparation on both the arrow side and the opposite side of Section "M".

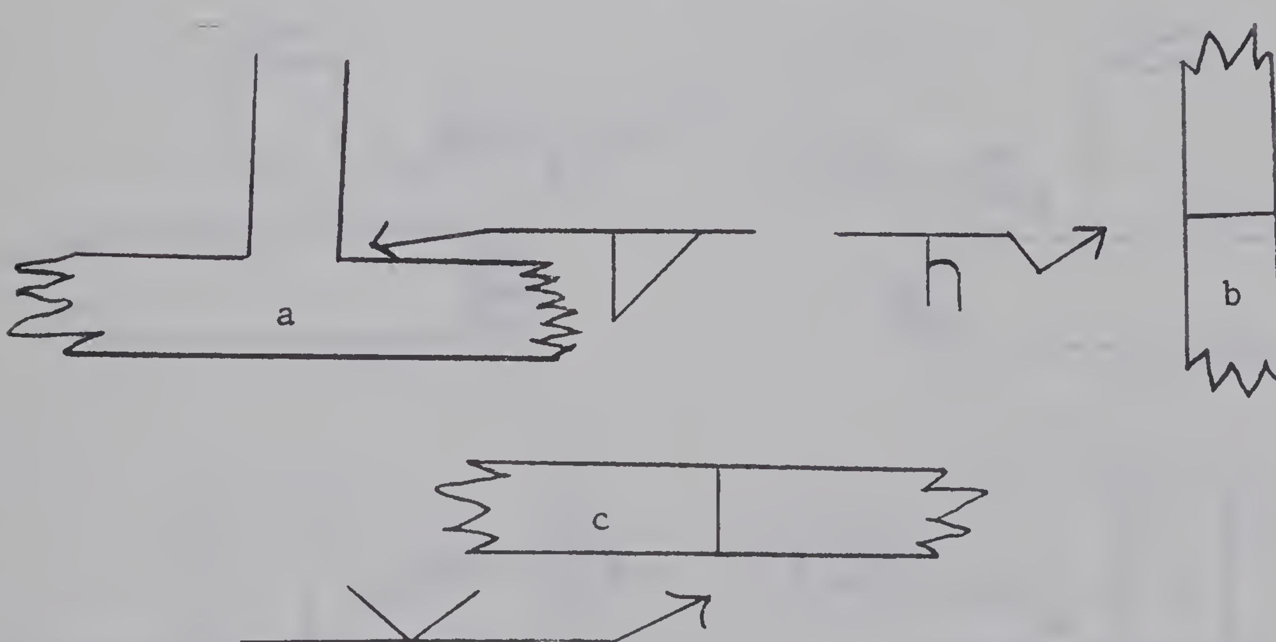
NOTE: In all illustrations the perpendiculars of symbols are drawn on the left side of the symbol.

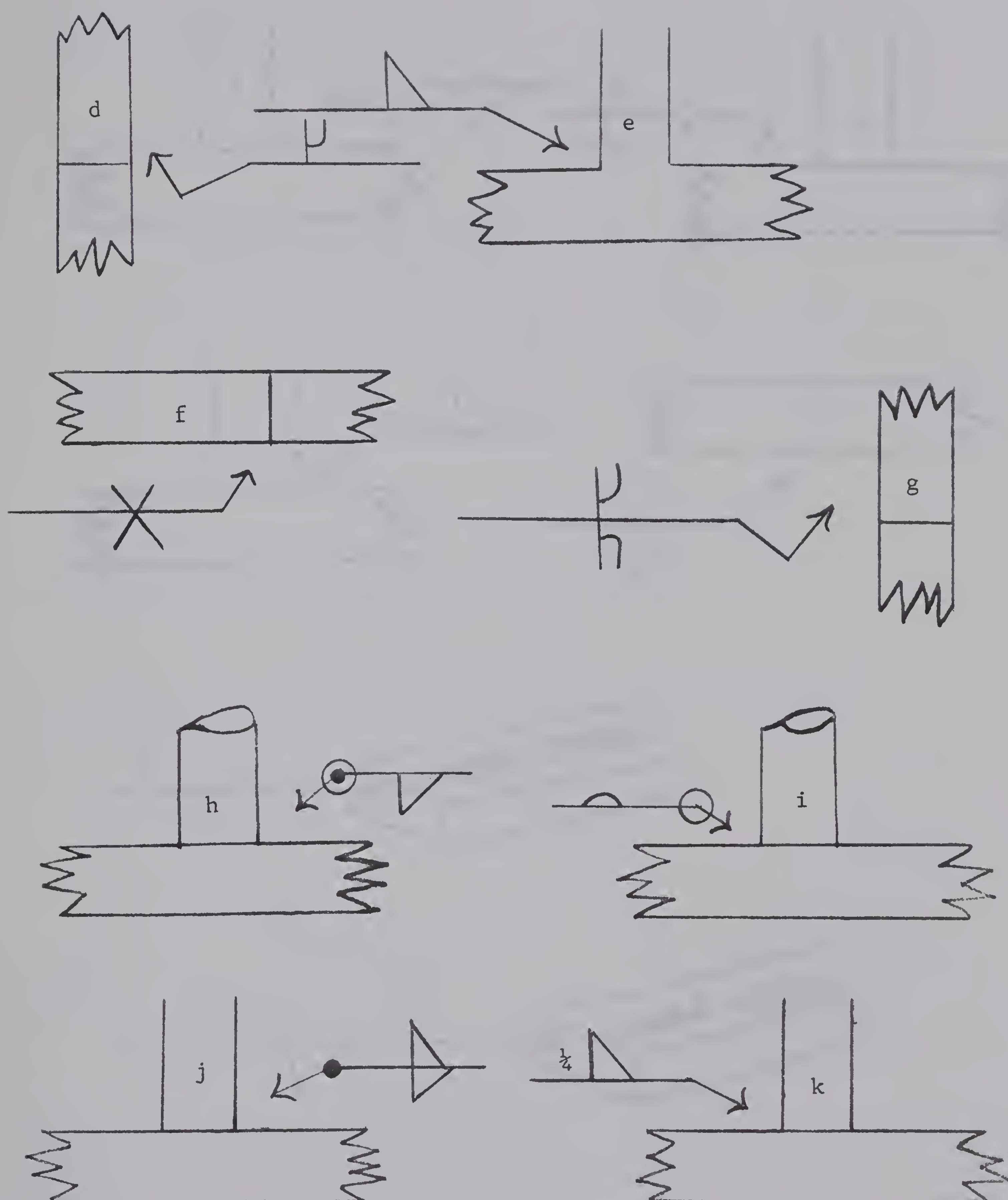
My experience with students reveals that through demonstration and illustration followed by the question and answer approach, more information and learning through self investigation is accomplished.

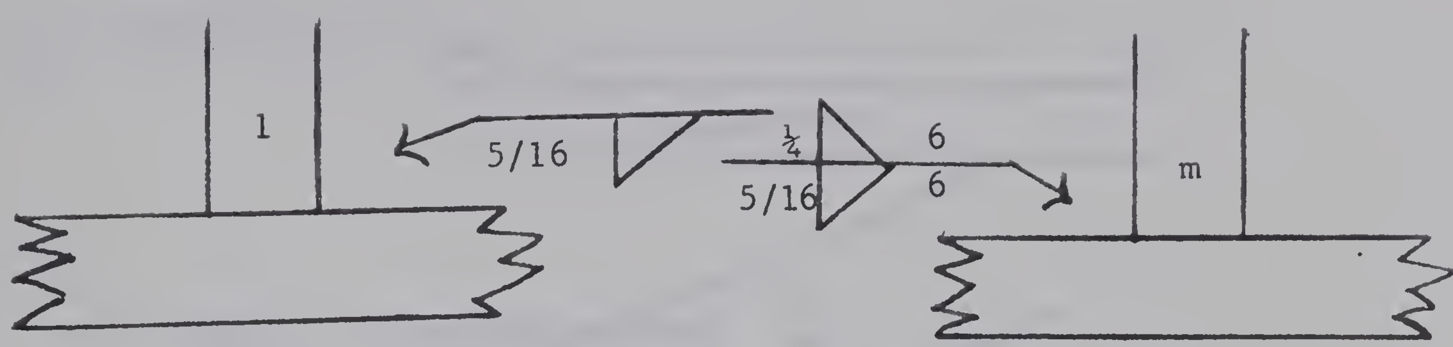
This method of self investigation will be illustrated in the use of various welding symbols through the following question and answer procedure:

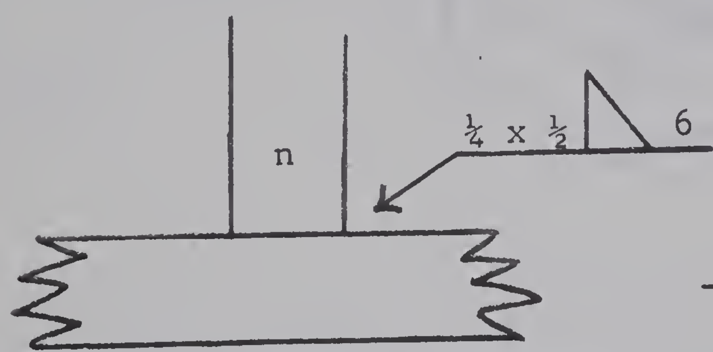
(1) How would you define the procedure required as illustrated by the following symbols?

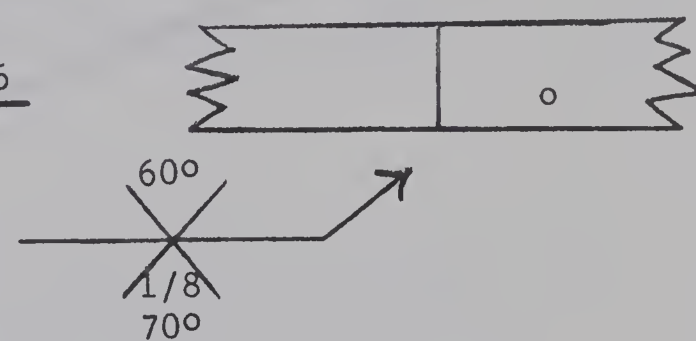
(2) By means of a drawing illustrate each.

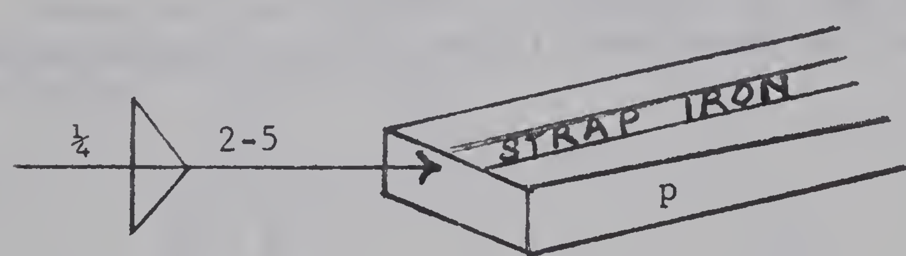


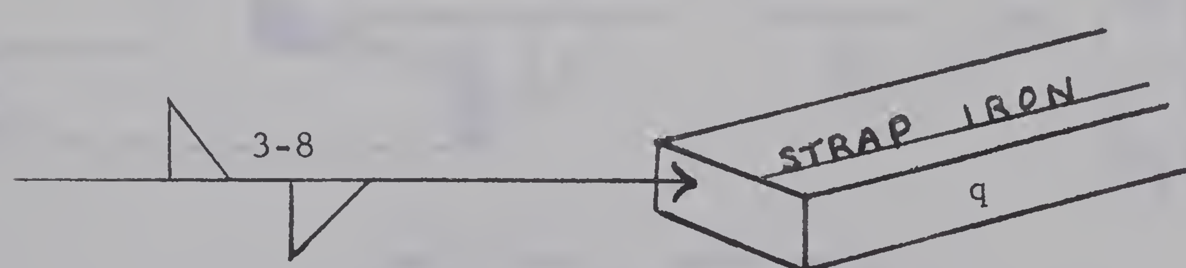

d
e
f
g
h
i
j
¼
k

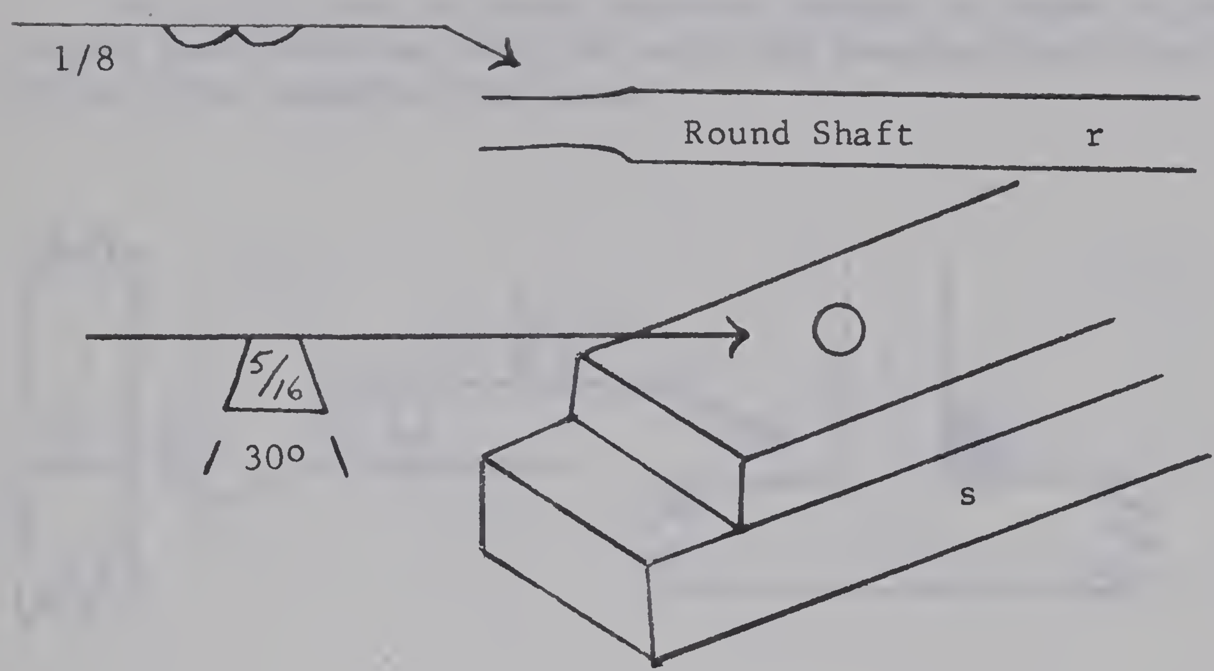

l
5/16
¼
5/16
6
6
m


n
¼ x ½
6


o
60°
1/8
70°

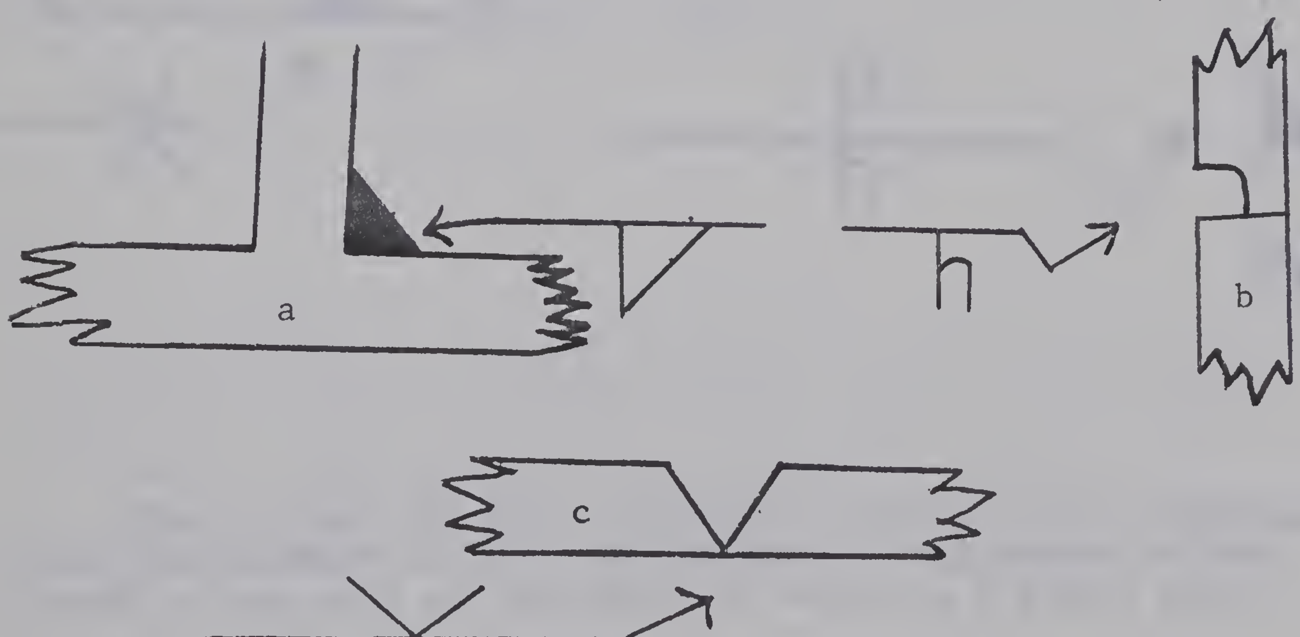

¼
2-5
STRAP IRON
p


3-8
STRAP IRON
q

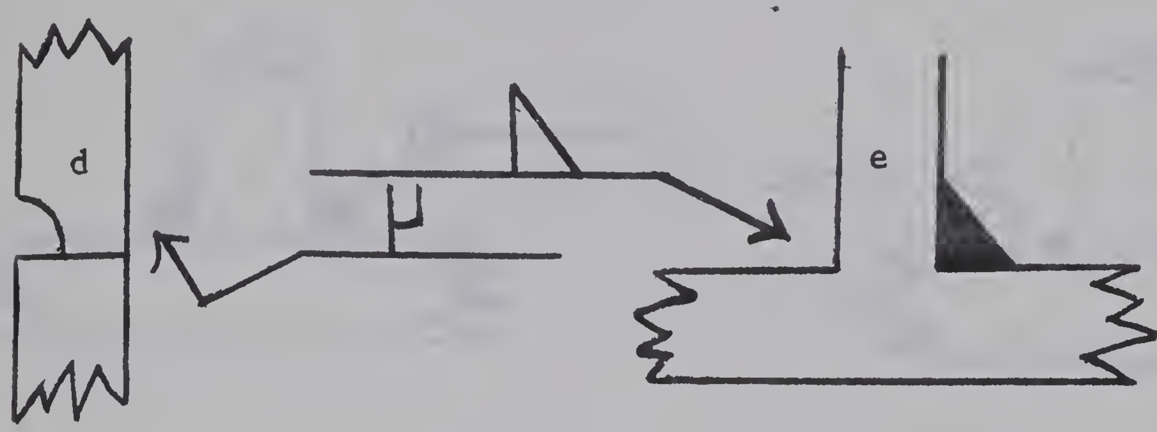


ANSWERS TO PRECEDING QUESTIONS

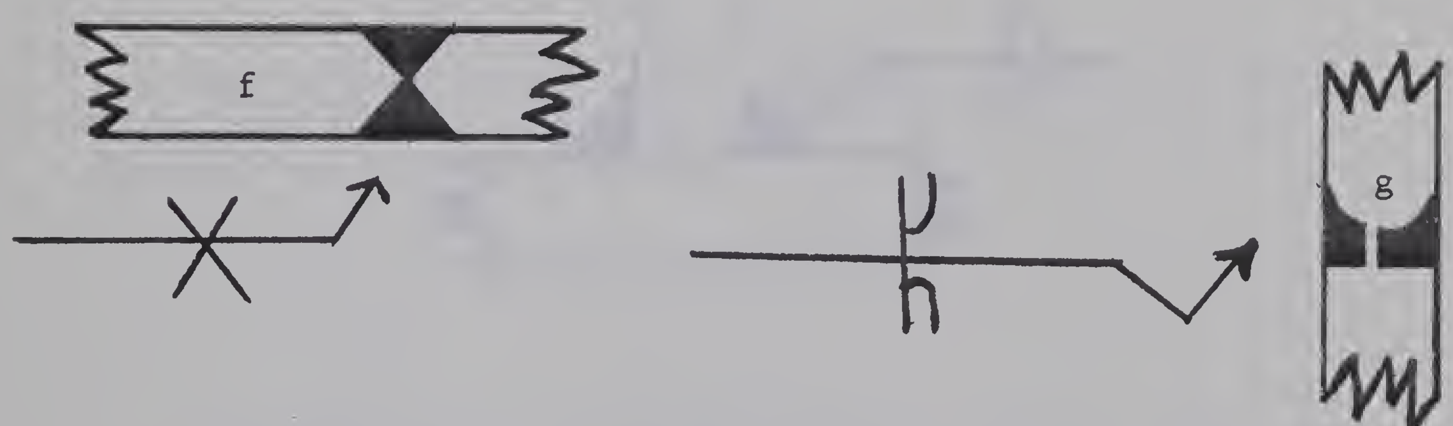
When the weld symbol is depicted on the bottom side of the reference line the weld is completed on the arrow side. See below.



As in (d) and (e) when the weld symbol is shown on the top of the reference line, the weld and preparation is made on the side opposite the arrow.

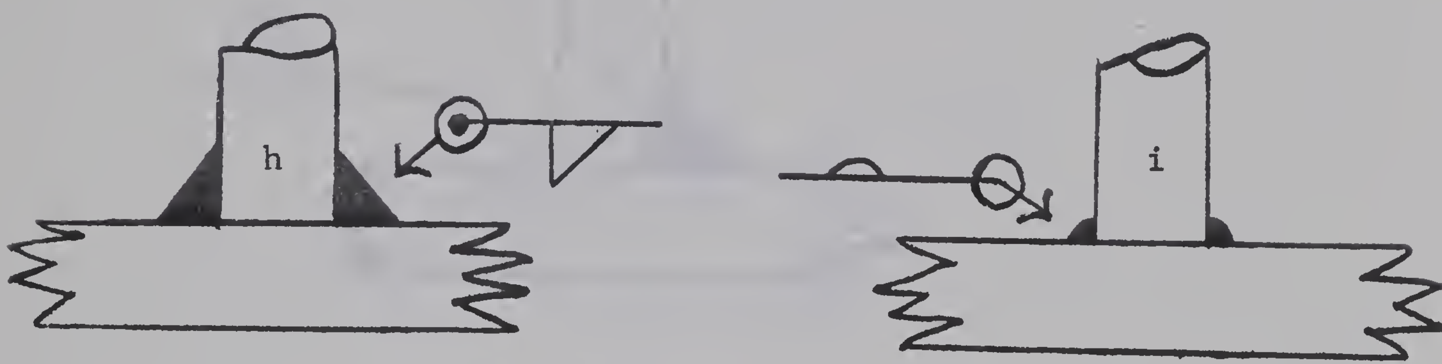


If symbols are placed on both sides of the reference line, welds and preparations are made on both sides of the joint. Note: (f) and (g).

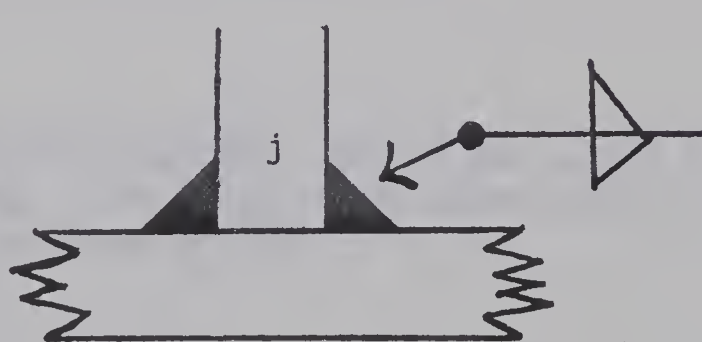


When a black dot and a circle are placed on the reference line the weldment is to be welded all the way around in the field (at the site of the job.) (h) would be a fillet weld.

A circle on the reference line, usually at the break in the line, denotes welding to be completed all around. (i) will be a bead weld.

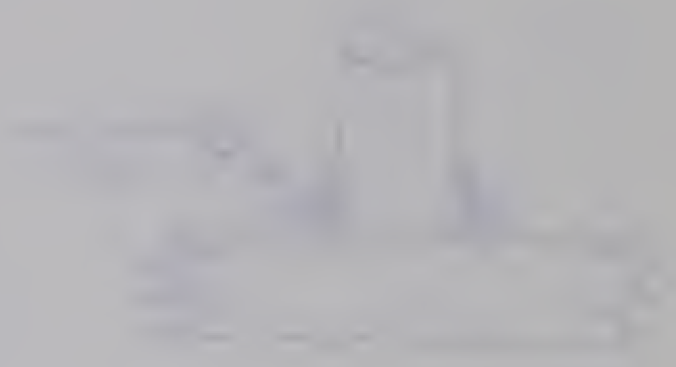


Since the black dot indicates the welding to be completed on the job, this on the job weld (j) would be a fillet on both sides of the joint.

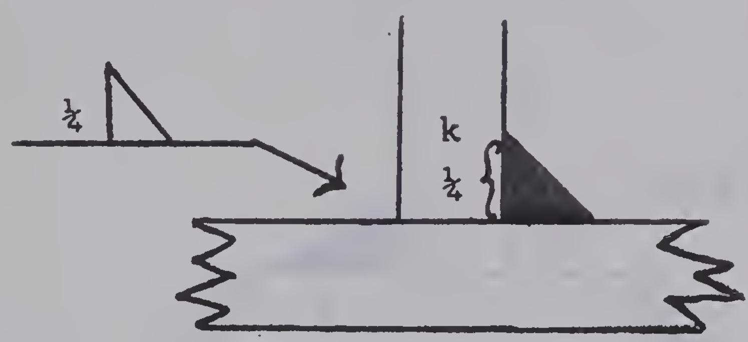


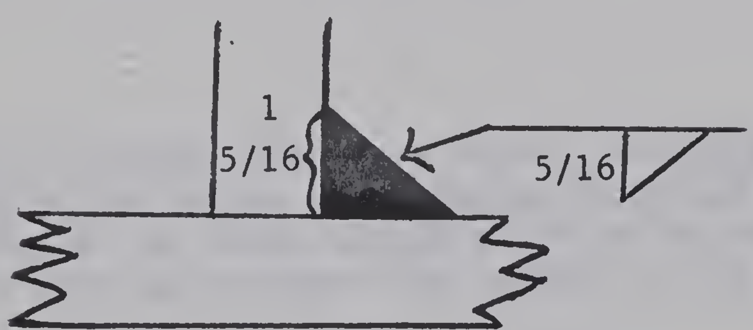
Dimensions of a fillet weld shall be shown on the same side of the reference line as the weld symbol. The size of the weld is shown on the left of the symbol. On the right side of the symbol is shown the length of the weld.

In (k) a ¼" fillet weld is made on the opposite side of the arrow.

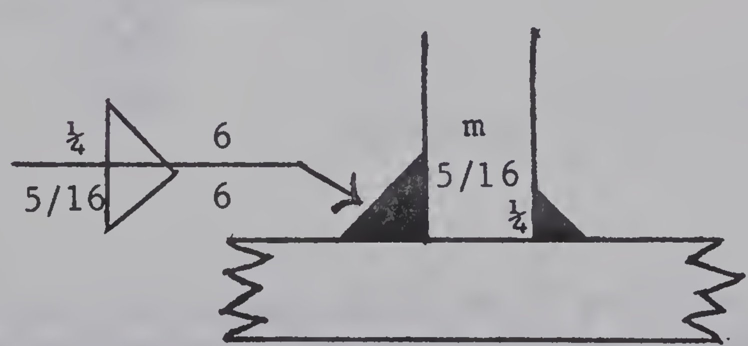


In (1) a 5/16" fillet weld is shown on the arrow side of the joint.

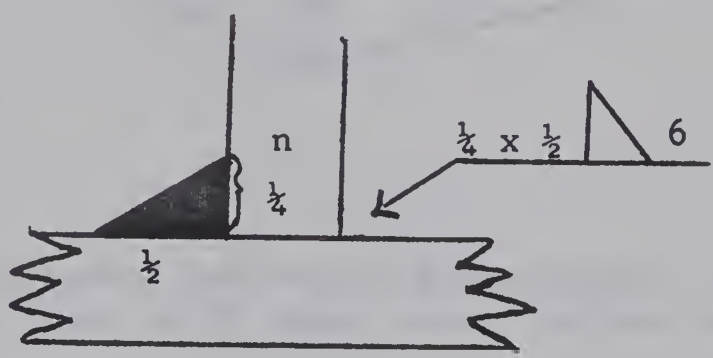




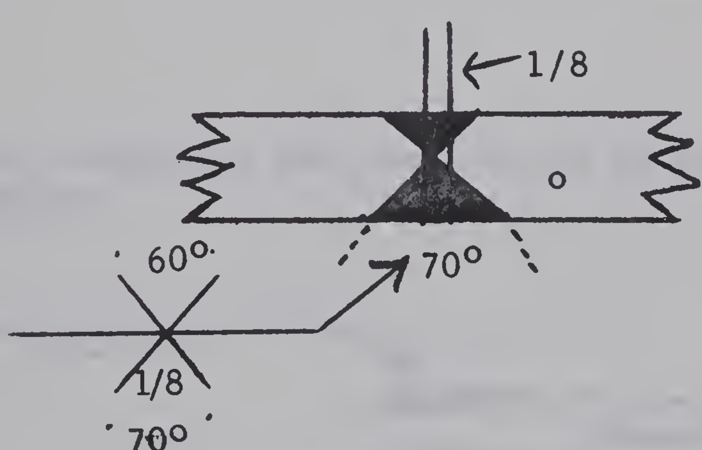
The weld on the opposite side of the arrow is a fillet of ¼" and 6" long. The weld on the arrow side is a 5/16" fillet 6" long as shown by (m).



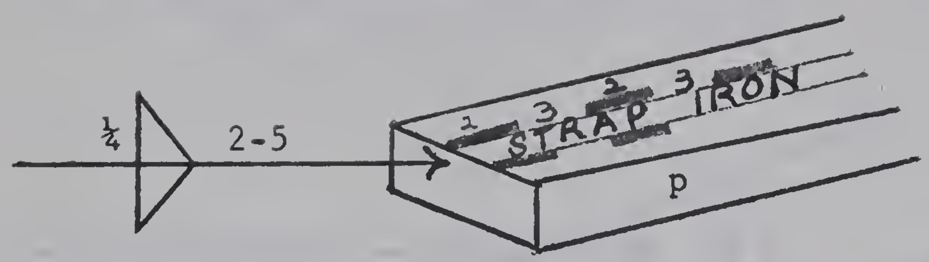
In (n) the weld is made on the side opposite the arrow. The weld is a fillet weld with the perpendicular leg ¼" and the horizontal leg ½" and the weld is 6" long.



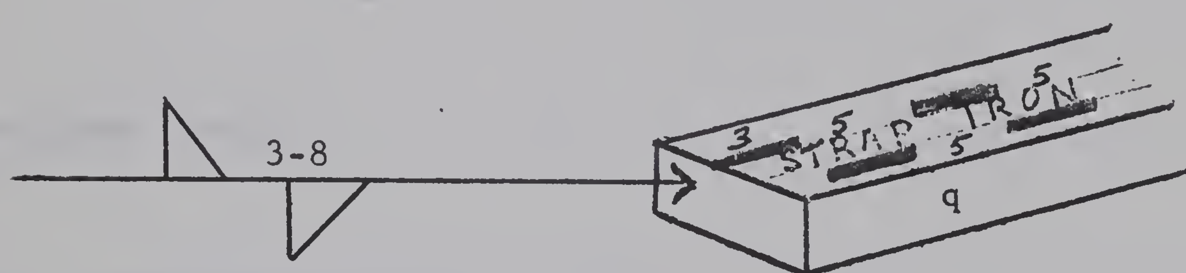
In (o) the symbol denotes a double "V" with the "V" on the far side of the arrow sixty degree included angle and the near side of the arrow having a "V" 70 degree included angle with a root gap between the pieces of 1/8 of an inch.



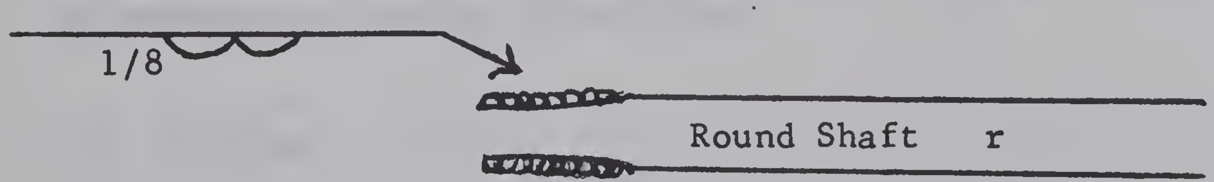
In (p) the symbol calls for a ¼" fillet weld on both sides of the joint. The weld will be 2" long with a pitch of 5". One would therefore weld for 2" and then leave a space of 3" between the end of the first weld and the start of the second weld to give the 5" pitch required.



In (q) the symbol represents intermittent fillet welds 3" long with a pitch of 8" which start on the other side of the arrow.

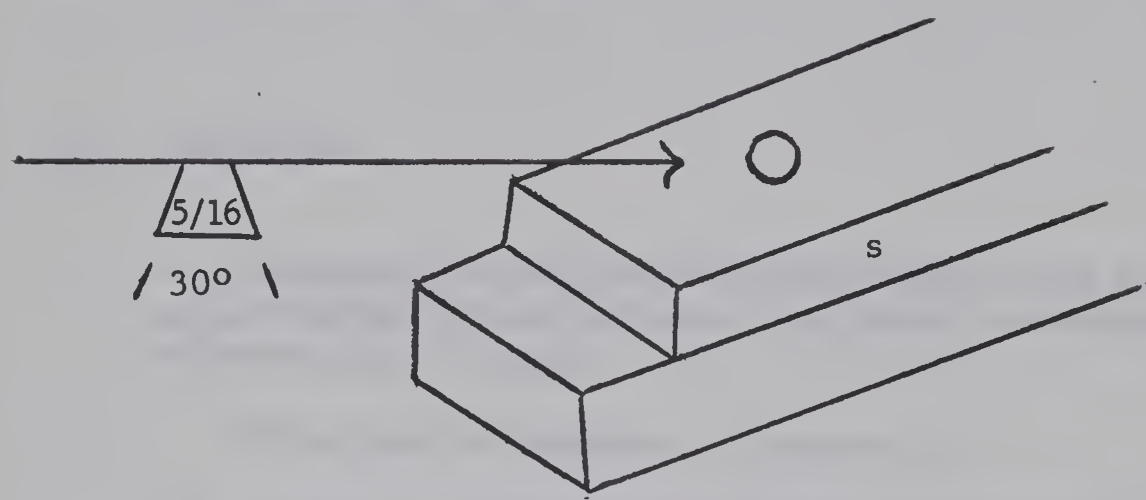


(r) denotes a bead weld build up on a shaft with 1/8" high beads.



In (s) the symbol denotes a plug and slot type of weld with the angle of countersink 30 degrees and the depth of fill 5/16 of an inch.

The following shows a plug type weld.



WELDING DEFECTS

A. DIMENSIONAL DEFECT

This is a weld fault in that the finished weldment deviates from the required measurement, shape, and quality required; and is created by such things as poor joint alignment, fit up and tacking. Consideration must be given to draw allowances in order to meet the problems of warpage or angular distortion.

(a) Warpage

NOTE: A condition where weld pull draws objects out of shape beyond the allowable level. The following methods alleviate the problem.

(1) The parts to be welded or cut should be clamped and left until completely cool.

(2) The cross-sectional properties should be such that they resist the forces or stress set up through heating.

(b) Distortion

Whenever welding takes place forces tend to cause distortion and without the proper techniques, weldments may distort.

This can be somewhat alleviated by:

(1) Using as little filler metal as possible and make good use of the weld metal that is needed.

(2) Using the right type of preparation and fit up. A minimum amount of weld metal will produce a strong joint if the joint is properly prepared.

(3) The use of larger rods and less weld passes, or intermittent welds will distribute the heat more widely through the weldment.

B. WELDING PROCEDURE DEFECTS

Slag Inclusions

This is a non-metallic material which is trapped in the weld and if not removed, the weld will suffer. The slag can be removed by chipping with a slag or chipping hammer before each successive weld bead or weave.

Undercut

This is a groove weld in the base metal which is left unfilled and is found adjacent to the toe of the weld.

Crater Cracks

A predominant surface crack in a weld crater. The under bead crack is found in the heat affected zone and not extending to the surface of the base metal.

Porosity

This is a common welding defect created by the presence of gas pockets or inclusions in welding.

Residual or Internal Stress

This defect is created by cold working or rapid cooling and accompanies fusion welding procedures. Precautions should be taken to remove the stress by a post heat treatment.

C. SERVICE DEFECTS

Corrosion

This is a rusting of iron with a similar action in deposits formed on other metals and is sometimes referred to as oxidization.

Fatigue

This is a failure of the parent metal while under dynamic stress, with inclusions, holes, undercuts and other defects contributing to cracking and eventual breakdown.

D. MATERIAL DEFECTS

Segregation

An uneven distribution of the elements in the alloy due to variations in their solidification temperatures.

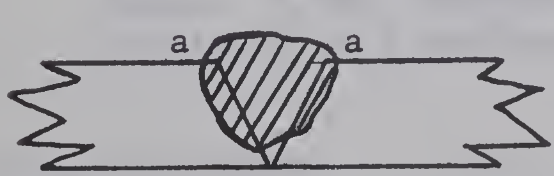
Coarse Grain

This is not only a characteristic defect of welding procedures but may also be a defect in the original material. Coarse grain materials are not as resistant to impact nor are they as tough or strong as fine grained materials.

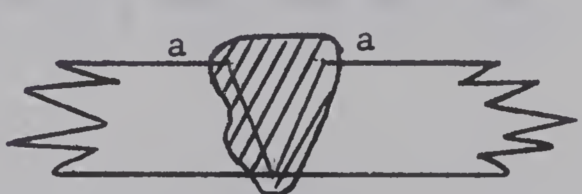
Blowholes

These are cavities caused by gas entrapped during the process of welding and taking place during the period the melted metal turns to a solid.

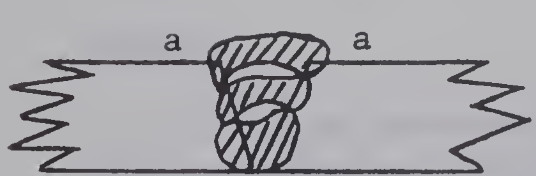
VARIOUS ILLUSTRATED WELD FAULTS



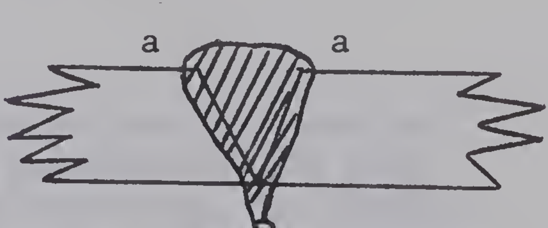
Root Penetration Incomplete



Root Penetration Excessive



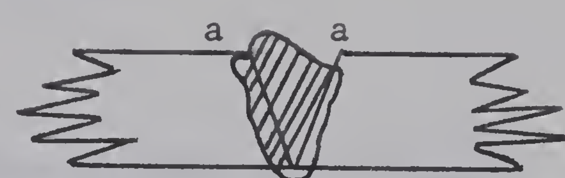
Incomplete Fusion Between Passes



Weld Dripping

NOTE: All the above have excessive build up and overlap at points "a".

Lack of Fill



Undercut at "a"

CAUSES OF COMMON WELDING DEFECTS

Fall Through

This is a condition where weld has sagged or fallen through. The expressions, icicles or weld drippings, are especially used in cast iron fusion welding.

Causes:

Excessive heat with a slow travel speed and poor joint preparation are a primary cause of such a weld fault. A well prepared joint with a root face will help eliminate this problem.

Slag Inclusions

The entrapped particles within the bead.

Causes:

If dirty material is not cleaned and prepared before welding and the operator is careless in the slag chipping process especially between welding bead applications, inclusions will be the result. Proper chipping of each weld pass combined with the proper arc length will eliminate the problem.

Lack of Fusion

The sides of the joint as well as each successive bead must be melted in order to take the filler metal which requires the proper flame heat or amperage.

Causes:

If the heat is not adequate and the arc is long, coupled with large fast beads, a weak combining of fluid metals will be the result.

Excessive Penetration

Complete penetration at the root face of a joint is mandatory, but should penetration exceed 10% of the parent metal, oxidizing of the metal could take place at the base, creating loss in tensile strength and ductility.

Causes:

Too much heat coupled with too small a rod, too large a gap, and slow travel creates the problem. When possible use backing strips (removable or permanent) especially when such a fault is likely to occur in the overhead position.

Lack of Penetration

This creates problems similar to excessive penetration in that tensile strength and ductility are lowered.

Causes:

Usually the cause which is opposite to the one for excess penetration can be overcome by increasing the heat and resetting the gap.

Porosity

This presents a pocked appearance in the surface area of the weld.

Causes:

Dirty parent metal of high sulphur or phosphorus impurities can create this problem as well as surface cracking. The use of proper type filler material can alleviate the problem in many cases with the proper amperage or heat. The oxides, by means of a flux, should be worked from the work area.

Overlap and Undercut

The overlap is metal which did not fuse completely but solidified prior to the parent metal reaching a melting temperature. Usually experienced on the excessive build up.

The undercut is the crater left in the molten parent metal which was left unfilled. Each of the above is responsible for lower ductility and tensile strength.

Causes:

The wrong speed of travel and rod inclination coupled with poor heat adjustment is mainly responsible for these common defects.

Notching Effect in Welding

When cast iron is nicked or notched by means of a hammer and chisel along a given line and then given a sharp blow, the material will break along the notched line. The above process would be similar to the glass cutting procedure.

Should a notch be left at the beginning or end of any welded material, even highly ductile material, the material could eventually fracture under stress due to the notching

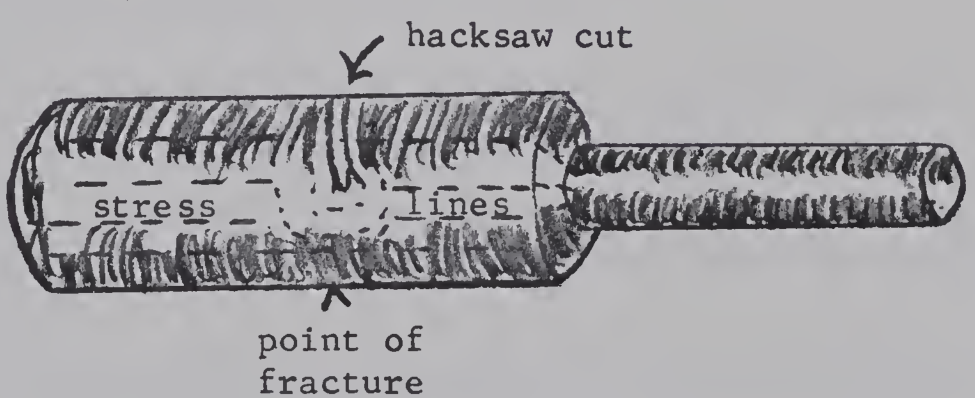
effect.

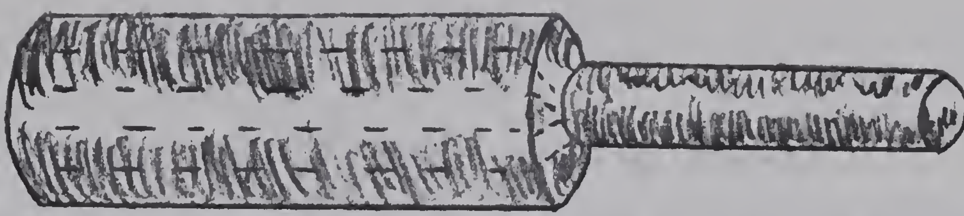
A bar of uniform dimension, when placed under stress, will have parallel stress lines exerted uniformly and evenly distributed throughout the bar; but should the bar be nicked by a hacksaw blade, then the stress lines are forced to by-pass the nick and thus by compressing each other in a smaller space, they place additional stress at the by-pass point. The deeper the sawed portion, the greater the stress at that point and the less dynamic stress necessary to create a break at that point.

With this in mind, the welder is prepared to Butt Weld two shafts of unequal diameters.

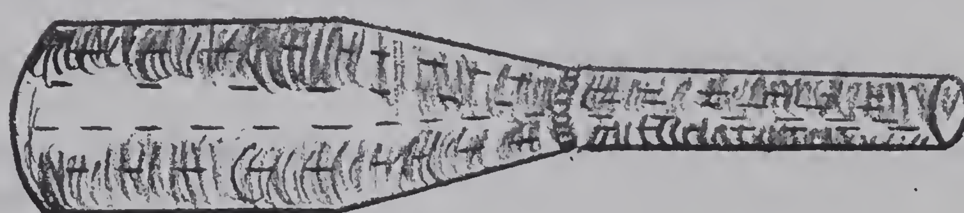
Since stress flow lines follow the contours of the materials, the welder would be advised to eliminate severe notching effects in the preparation, and allow the flow lines of stress to taper out gradually.

The following examples should be considered and understood:





Before welding, prepare as illustrated below:



Preparation for Welding

QUESTIONS TO SECTION II

1. What are the five (5) basic welding joints?

2. What are the three (3) basic welds mentioned in this section?

3. Name the five (5) common types of Groove Welds.

4. What is another name for the Plain Butt Weld?

5. Give the name which is sometimes used in place of Plug and Slot Weld.

6. What are two (2) types of Bead Welds?

7. How would you explain an Intermittent Weld?

8. Name the four (4) positions in which welding could be done.

9. How would you describe the horizontal welding position?

10. What information is given from the tail of the arrow as a welding symbol?

11. What is meant when the weld symbol is placed on the arrow reference line away from the reader?

12. What must a welder assume when a black dot is placed where the arrow makes a definite break from the reference line?

13. Where is the size and the length of a weld shown when using a weld symbol?

14. What do the letters G, C, and M mean when used with a Flush, Convex or Contour symbol?

15. What does the welder assume when dual Bead Weld symbols are placed in the reference line?

16. What are the four (4) basic categories of weld faults?

17. What are three (3) common names for gas inclusions in welding?

18. Explain the term "Slag Inclusions" used in welding.

19. What must be known about the perpendicular leg to properly draw a Fillet, Bevel or J Groove Weld symbol?

20. What is designated on a welding blueprint when a circle is placed where the arrow makes a definite break from the reference line?

WELDING

SECTION III

METALLURGY AND METALLOGRAPHY

The physical properties of any metal depend on the alloys of which the metal is composed and the impurities within the alloys. The type of temperature treatment coupled with hot and cold working, and the overall manufacturing procedures lend to the grain size and structure of the metal. It should be realized that structures may be quite varied in grain size (inherent grain sizes) even though the process producing the metals has a similar procedure and analysis.

Carbon is considered the most important element of steel, and the physical properties are determined by the carbon content. When steels are heated with a torch or in a furnace they eventually reach what is described as their critical point. This is the point reached during heating where the steel becomes non-magnetic.

Steels under .15% carbon content can be described as low carbon or mild steel, and if these steels are quenched from a temperature just above the critical point, a fine grained tough material with little increase in the hardness will be produced.

When heating a steel by means of welding we have an adjacent affected area, the size of which is dependent on the thickness of the material and the welding procedure. The width of the affected zone is greater in gas welding than in arc welding. Welding by means of multiple beads gives an improved structure to the deposited metal. Each successive layer is deposited while the previous bead or layer is brought to the above mentioned critical point for a fine grained, tough structure.

Fractures at the edge of a weld, even in low carbon steel, can be due to increased hardness caused by the steel

absorbing nitrogen or oxygen from the air. However, in the affected zones on either side of the weld, the hardening effect is limited due to a lack of the hardening element carbon. In gas welding, a carbonizing flame could increase hardness in the steel due to the fact that carbon can also be absorbed into the material from this carbonizing flame.

Carbon steels can be hardened by various methods. Steel heated to its upper critical temperature can be quenched in oil as well as water. Hardening of steel by means of air at room temperature rather than by the quenching water method is known as "air hardening" of steels. The higher the carbon content of the steel, the harder the material becomes when the above hardening procedures are used. Steels can become so hard as to be brittle enough to break under light impact.

METALLOGRAPHY

This can be described as the microscopic study of the structure of metals and alloys. Grain structures of metal influence its properties. By means of metallography the grain structures of metal are studied to determine how the different properties are affected by the structure of the materials.

The three factors which are most important in the control of the structure of a piece of metal are:

(1) Composition.

(2) Heat treatment.

(3) Mechanical Treatment.

Any or all of the above factors determine the usefulness of any weldment in standing up to specification for which it has been fabricated.

METALLOGRAPHIC TESTS

These desirable tests may consist of:

(1) a microscopic examination where etched pieces are magnified many times.

(2) visual examination of etched macrospecimens. The pieces are etched to bring out the grain structure.

The above tests will determine the number of weld passes, the size and variation of inclusions as well as the structure in the weld and fusion zone.

FERROUS AND NON FERROUS METALS

Ferrous metals are metals having a high iron content, easily oxidized in moist air, attacked by many reagents and usually magnetic. Non Ferrous metals are those which contain no appreciable amount of iron such as tin, platinum, aluminum, copper, nickel and their alloys.

METAL IDENTIFICATION

Welding procedures vary according to the type of material to be repaired, therefore, the welding operator must practice metal and alloy recognition especially between various types of cast iron and carbon content steels.

Metals can be closely classified by:

(1) appearance.

(2) melting temperature.

(3) chip test.

(4) Spark Test.

(5) Weight.

IRON AND STEELS

Iron

Iron is a tough, malleable, ductile, and strongly magnetic metallic element found in a number of different forms but usually as an iron oxide. The iron ore can be recovered by the strip or underground mining methods. Iron is seldom obtained in its pure form which is silver-white in color, but occurs widely in both ferrous and ferric compounds, and combines in varying proportions with carbon, silicon, sulphur, phosphorus, etc.

Iron ore is reduced to metallic iron in the blast furnace which, when poured, is called a cast of pig iron. Iron in its pure form, although it resists corrosion even when placed in pure water, is of no commercial value as it is too soft. The iron is alloyed with other elements such as manganese, sulphur, chromium, copper, aluminum, nickel and many others. Although phosphorus and sulphur are used as alloying elements they are also considered to be impurities when alloyed in large quantities. Sulphur is sometimes added to steel to improve the machining qualities by making the material softer. Aluminum is also used in steel making for fluxing purposes. The properties of the alloyed material will depend on:

(1) The percentage of alloying element added.

(2) The amount of other elements present.

(3) Treatment of alloy during cooling.

(4) Work hardening or heat treatment after solidification.

Wrought Iron

Can be classed as a commercial iron produced by a puddling furnace or a forge, and containing very little carbon or other substance. Wrought iron is usually quite fibrous, ductile and malleable, and highly resistant to corrosion and fatigue.

The welding done on wrought iron will be found very sound since the material can withstand high welding temperatures, while natural slag in the metal has a fluxing effect which protects the metal in the heating process. Wrought iron can be satisfactorily repaired with pieces joined by the braze-welding method.

Steel

Steel is a tough alloy of iron containing the element of carbon in varying amounts. Under the proper conditions it is quite malleable, but in turn can be greatly hardened by the proper process.

For convenience, steels are categorized according to the percentage of carbon content into the following three classes:

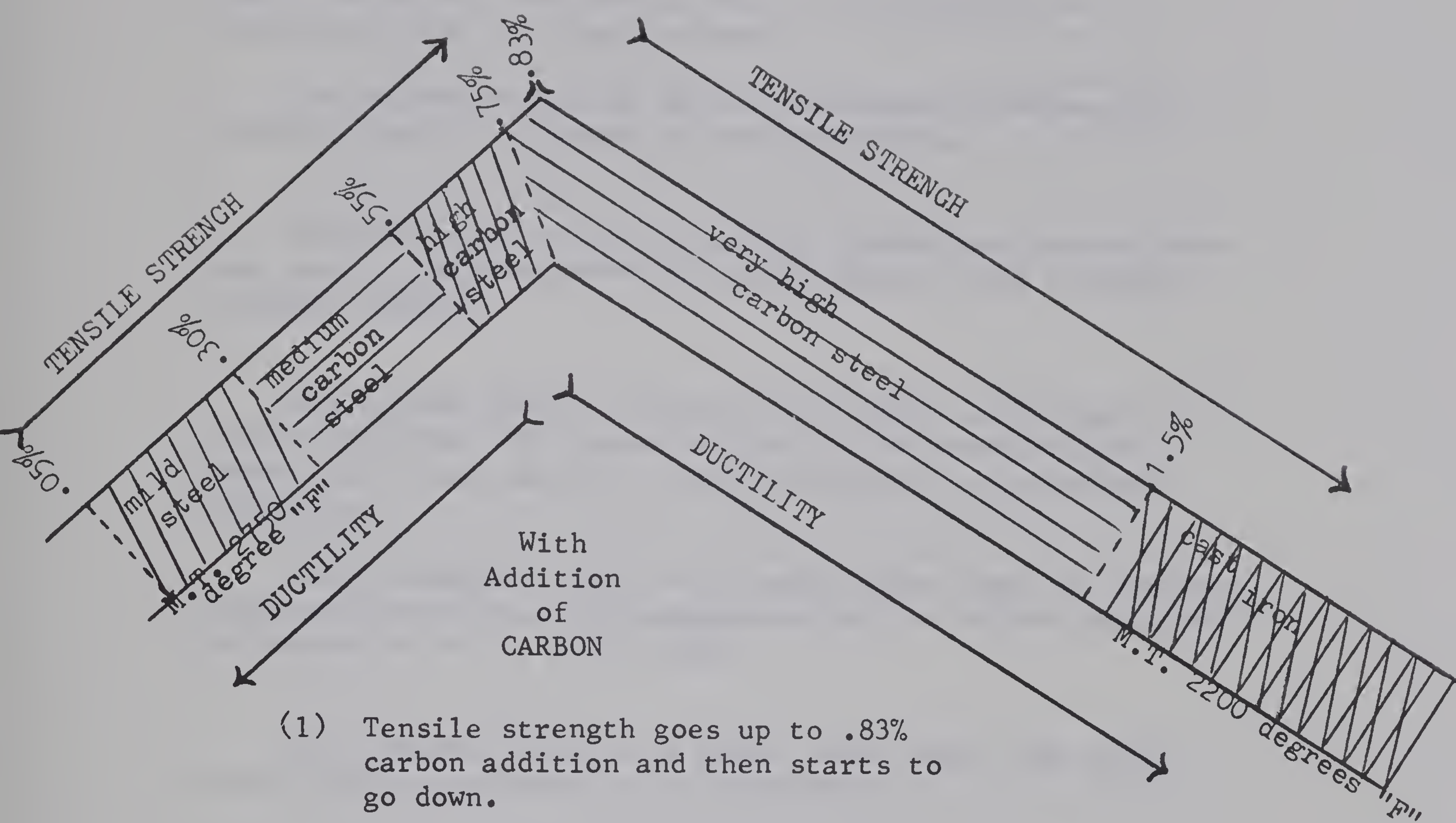
(1) Low-carbon or Mild steel.

(2) Medium carbon steel.

(3) High carbon steel.

CHARACTERISTIC CHANGES IN STEEL BY THE ADDITION OF CARBON

To aid the welder to better understand the effects of the alloying carbon on the properties of steel even though the amount of carbon increase is small, the following illustration is given:



(1) Tensile strength goes up to .83% carbon addition and then starts to go down.

(2) Ductility starts to drop with the addition of carbon.

(3) Melting temperature is lowered with the addition of carbon.

As the carbon content is increased the melting temperature is lowered, steel is harder and stronger, more wear resistant, cracks easier on welding, harder to machine but up to a point is easily heat treated.

Tensile goes up as carbon content is increased only to a point of .83% carbon. As carbon is further increased the tensile strength drops to the point of brittleness in the cast iron area. Ductility continues to be lowered continuously as the carbon content is raised.

Steels must have a minimum of .30% carbon to be successfully

heat treated and steels with over a .50% carbon content should not be flame hardened.

The welder should be able to distinguish between the following metals by means of the spark test.

WROUGHT IRON contains almost no carbon but when in contact with a grinding stone it gives off dull red straight streaked sparks.

LOW CARBON STEEL contains only a small percentage of carbon and gives off sparks similar to the wrought iron except that they explode in wider lines and are somewhat brighter.

MEDIUM CARBON STEEL having more carbon than the previous types will have star-like explosions with a bright spark when in contact with the emery wheel.

HIGH CARBON STEEL has a white bright star type spark which ignites explosively and disappears.

NOTE: The welding operator must not confuse the above carbon steels with the HIGH SPEED STEEL which contains little if any carbon and gives off dull red sparks similar to cast iron but which have a tendency of following the circumference of the grinding wheel.

CAST IRON

Grey Cast Iron

Pig iron which has been remelted and poured into a certain shape or form is cast iron. Cast iron, due to its high carbon content, 1.7% and up to as much as 6.00%, is very brittle but is used commercially owing to cheapness in the manufacture of cast parts for machinery purposes which do not require strength.

Grey cast iron is the most common type of cast iron and must contain at least 1% silicon along with its high carbon content. Cast iron is impregnated with graphite from parts of separated carbon. Since graphite is a lubricant and welding would not adhere to such a surface, the best approach for brazing preparations would be to sear the surface to be welded with an oxidizing oxy-acetylene flame. Post-heating and pre-heating procedures would assist the welder in many cases.

White Cast Iron

This is the hardest type of cast iron and is unweldable and when broken, the break appears silvery and white with little noticeable graphite. Further information can be obtained by referring to the various listed books for reference purposes.

Malleable Cast Iron

This is a cast iron which is made soft, strong and malleable. Some carbon has been burned out which reduces the carbon content to less than 2.5%. Being softer and malleable, it will withstand shock and blows better than grey cast iron and will bend before breaking. The broken malleable cast iron will be dark and dull at the center with a bright skin at the surface edge. This material cannot be fusion welded since the heat necessary to melt the material for fusion will destroy its malleable properties. For this reason, malleable cast iron should be brazed.

COMMON ALLOYING ELEMENTS

An alloy is a mixture with metallic properties and is composed of two or more elements, one of which is a metal.

Aluminum

The element "aluminum" is widely distributed in the form of aluminum oxide. The melting temperature is 1220 degrees fahrenheit. Aluminum is used in steel to restrict the growth of austenitic grains and can be classed as an oxidizer.

Beryllium

This is a metallic element which resembles magnesium. It is used for hardening purposes in copper. The alloy is used in hard non-sparking tools. It is slightly heavier than magnesium and has the highest strength-to-weight ratio of any metal. Melting Temperature - 1280 C.

Boron

Small quantities of Boron gives steel a greater hardening ability but if more than .006% Boron is added to steel, the resultant metal is similar to high sulphur content metal. Melting Temperature - 2300 C.

Cadmium

This is a bluish-white metal which is malleable and ductile. It is used in the manufacture of fusible plugs. Cadmium fumes, although not as toxic as Beryllium, should be recognized as a danger when alloying or welding. Melting Temperature - 321 C.

Carbon

This is the most important element in iron due to the resultant property changes that take place. High carbon alloying of steel could create surface holes and rough surface appearance. High tensile strength and good weld ability can be obtained by lowering the percentage content of the carbon and adding additional other elements. Melting Temperature - 3500 C.

Chromium

Chromium increases the hardness and abrasion resistance of steel. The addition of chromium to steel aids in a finer grain structure which increases strength, ductility and corrosion resistant properties. Preheating before welding chromium alloy steels is usually required procedure. Air hardening steels are produced by adding a 5% chromium while not less than 12% will produce a stainless steel. Melting Temperature - 1615 C.

Cobalt

This alloying element is necessary when steel must keep the property of hardness under extreme heat. Melting Temperature - 1467 C.

Columbium

Intergranular corrosion in a weldment made from an austinitic chromium-nickel steel can be prevented by the addition of columbium acting as a carbide stabilizer.

Copper

Corrosion of steel can be alleviated somewhat by adding the alloying element, copper. One percent of copper alloyed with steel has no detrimental effect on the welding operation. Melting Temperature - 1082 C.

Magnesium

Magnesium alloys can be fabricated without difficulty and have been developed with high strength properties. It alloys readily with aluminum, manganese and silicon to form structural alloys. The strength of the alloys are comparable to aluminum alloys and weight is only 65% as much. Melting Temperature - 651.6 C.

Manganese

Manganese, when an alloy of steel, aids the tensile strength and makes for a work hardening material. External and internal cracking results from the wrong percentage addition of carbon. It forms carbides and removes sulphur while also acting somewhat as a deoxidizer in steel. Melting Temperature - 1230 C.

Molybdenum

This is a silver-white metal which gives strength and hardness to steel so it will withstand heat and impact. It also gives the qualities necessary for tool steels. In stainless steel, molybdenum improves the resistance to acid corrosion. Melting Temperature - 2535 C.

Nickel

When nickel is alloyed with steel the strength is increased as well as the toughness. Steels having more than 24% nickel will be found non-magnetic. Armor plate, a hard strong material, is made from a chrome-nickel steel containing chromium and nickel. Melting Temperature - 1452 C.

Phosphorus

Phosphorus, like sulphur, can be classed as an impurity in steel and should be kept as low as possible in the steel making process. The fluidity of iron is increased through the addition of phosphorus while the shrinkage is decreased and corrosion resistance somewhat improved, especially in the low carbon steels. Melting Temperature - 44.2 C.

Silicon

This element, if used with manganese, also increases

the tensile strength of steel. Silicon should not be alloyed with high amounts of carbon since the result would be a metal susceptible to cracking. It also acts as a deoxidizer. Melting Temperature - 1420 C.

Sulphur

The addition of sulphur gives steel an improved machinability. Sulphur should not exceed .05% in the alloying steel process since above this percentage welds have a tendency to crack due to residual stress set up in welding. Low hydrogen rods can be used satisfactorily on high carbon and high sulphur steels. Melting Temperature - 900 C.

Titanium

This white metal is the only element which will burn in nitrogen. When alloyed with steel it will disperse the sulphur. It is also a powerful carbide former. Melting Temperature - 1850 C.

Tungsten

This is a self-hardening agent. The melting point of tungsten is higher than any other metal. Metal alloyed with tungsten has a fine grain with a hardness which will withstand heat. Tungsten carbide, a metal almost as hard as diamonds, is made by alloying tungsten and carbon. Melting Temperature - 3400 C.

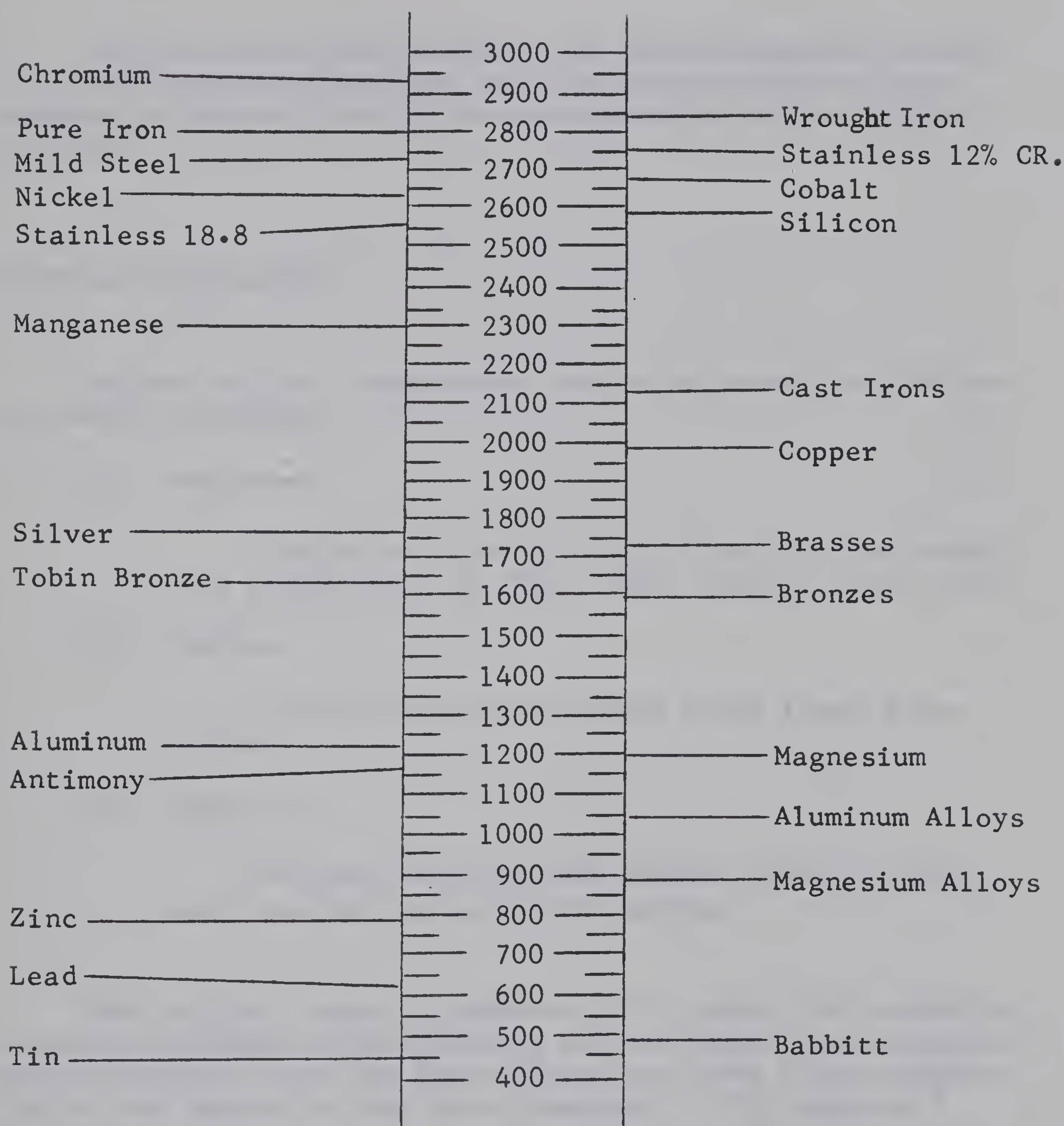
Vanadium

This alloying material like Molybdenum, Tungsten, and Chromium are carbide formers so necessary in tool steel to give cutting properties. Vanadium promotes fine grained structures in the high speed steels. Melting Temperature - 1780 C.

Zinc

This metal forms copper-zinc alloys known as brass. Since it oxidizes slowly it is used in galvanized iron. Thirty percent zinc, twenty percent nickel and the balance in copper is alloyed to produce German Silver for the purpose of making cheap jewelry. Bronze, besides containing copper and tin, also contains zinc. Melting Temperature - 419.4 C.

MELTING POINTS OF METALS AND ALLOYS



HEAT TREATMENT OF STEEL

We have placed the processes of Steel Treatment in the following order in the hopes that an understanding of each successive one will aid in the comprehension of the following one.

CRITICAL TEMPERATURE

Before critical temperature can be explained the following will be defined:

(1) Austenite

A solid solution in iron of carbon that occurs as a constituent of steel under certain conditions.

(2) Ferrite

A solid solution in which alpha iron is the solvent.

(3) Cementite

The hard brittle iron carbide found in steel, cast iron and iron-carbide alloys.

The critical range of temperature is where the austenite (magnetic) changes to the ferrite and cementite (non-magnetic). This is divided into the upper limits or lower limits depending on the purpose of the heat treatment. 1292 degrees F. is the temperature of the lower limits with the higher limits depending on the carbon content of the material. The grain is finer when steel is heated to the critical temperature, and if quenched suddenly this fine grained structure remains intact, giving a hard material. The critical temperature is lowered as the carbon content of material increases. Steel is magnetic until the critical temperature is reached.

PREHEATING

This is the application of heat before welding in order to offset or compensate for residual stress (internal) or distortion, and at the same time improve the quality of the weld, when possible to do so, through a heat treatment.

Preheating can be accomplished by means of the oxy-acetylene torch or other fuel burning preheating torch. This method is satisfactory for small areas or isolated localities but when the complete unit must be preheated a forge fire or a permanent preheating furnace should be used.

Preheating lowers the cooling rate of the finished weld which helps to eliminate the possibility of breakage in the adjacent weld zone and also eliminates major crack formation.

RECOMMENDED PREHEAT TEMPERATURES

Mild Steel	.05%	-	.30%	....	250° F.
Medium Carbon	.30%	-	.55%	....	600° F.
High Carbon	.55%	-	.75%	....	700° F.
Very High Carbon	.75%	-	1.5 %	....	800 plus F.
Manganese Steel			12.0 %	....	Not reqd.
Stainless (18% Cr. - 8% Ni.)				....	Not reqd.

POSTHEAT

This is a process of heating metal after welding or cutting in order to temper the heat affected zone adjacent to the weld, and to relieve the residual stress to some degree.

ANNEALING

This is an operation where the material is heated and cooled relatively slowly in order to remove the stress, as in post heating; or for the purpose of making a hard ferrous material soft and, therefore, altering the physical properties such as ductility and toughness.

The type of material and the purpose of the operation will be the basis for the temperature and the rate of cooling necessary. The slower the cooling, the softer the material will be when cold. A good guide for the heating temperature is a point just above the critical point. If the heated material is placed in hot ashes, asbestos or lime, the cooling is retarded. Non-ferrous materials such as copper, must not be confused with ferrous annealing procedures since the copper is softened by heating and quenching in cold water.

STRESS RELIEVING

Residual stress (internal stress) created through welding must be eliminated by a post heating process. Temperature for stress relieving is always below the critical range while temperature for annealing and normalizing is always above. Heat treatment to relieve stress should not be within the critical range since this creates not only distortion but also changes the grain structure and dimensions which would create a defect in the weldment.

Plain carbon and low alloy steels must soak at varying temperatures, usually around 1100 degrees F. to 1250 F., depending on the thickness of the material. Slow rate of heating and a slow rate of cooling are very important in the stress relieving process.

Materials that have shown distortion after welding are usually free of residual stress, but on reheating for the purpose of correcting dimensional defects, the above relieving process should be used followed by peening.

HARDENING

Steels below .83% carbon content can be heated above the critical range and quenched in air, water or oil to form martensite (solid solution of iron and up to 2% carbon) producing high strength, wear, resistance and hardness. For the development of full hardness the cooling rate varies depending on the composition of the steel. Steels below .30% carbon can be somewhat hardened but it is usually not practical.

TEMPERING

Tempering or drawing is a process which takes place after hardening in order to make the hard material tough rather than brittle. The hardened steel is reheated to a temperature below the critical temperature. The reheating process breaks down the martensite to a ferrite matrix of iron carbide particles. With a lower carbon content in the steel, toughness will be predominant; less hardness when a higher tempering temperature is used. Post heating of a weld area creates a tempering effect in the adjacent weld zones and relieves stress. Oxy-acetylene welding will feather out the tempering area over a greater area than arc welding, and usually post heating in the former case is not always necessary.

NORMALIZING

The welded material, especially near the weld area is heated above the critical range and allowed to cool in the air, well out of drafts. This improves the mechanical properties by refining the grain size.

FLAME HARDENING

By means of the oxy-acetylene torch a small surface from 1/16" to 1/2" is heated above the critical range and quenched. The surface heated is immediately hardened and the underlying portion is in the original condition. Only the areas necessary for wear resistant properties can be treated, leaving all other areas machinable and ductile. The physical properties are changed and the chemical composition remains constant during this process.

Carbon steels from .30% to .50% create very little difficulty in flame hardening but steels above .50% could fail due to cracking encountered in the quenching process. Cast steel, although not as suitable for flame hardening purposes as forged steel, can be given the flame hardening treatment if precautions are taken. Flame hardening of cast iron and alloy steels depends entirely on the constitution of the metal.

CASE HARDENING

This is a form of carburizing and is similar to flame hardening only in that the outside limit of the material is hardened.

Carbon is added to the surface of the metal leaving the interior unchanged. Only wrought iron and low carbon steels can absorb the carbon through the case hardening method, whereby the surface or outside is converted into a tool or high-carbon steel. The material to be treated is placed in an enclosed container in which materials containing high quantities of carbon have been placed. The container is heated to about 1800 degrees F. and the steel soaks up the freed carbon.

The thickness of the case, or the depth of carbon penetration, depends on the length of heating time. After the case hardening process, the material can be hardened by the hardening procedure, care taken to not burn out the added carbon. Potassium cyanide, burnt leather, bones and charcoal are good materials for supplying the carbon.

WELDING TEMPERATURES

The arc welding process creates a temperature which is dependent upon the graphite content of the rod and the length of the arc. The temperature of the arc would be considered equal to the boiling point of the electrode, and can be affected by the three forms of heat transfer; radiation, conduction and convection, as well as the pulsation of the current. The temperature of the metal arc is approximately 6000° F. while the carbon arc could reach a maximum temperature of 9550° F. In oxy-acetylene welding the flame which is strongly oxidizing could reach a temperature of 6300° F.

WELDING HEAT

The welder should be familiar with the meaning of two closely associated welding terms; Temperature and Heat.

The British Thermal Unit is the quantity of heat required to raise the temperature of one pound of pure water one degree fahrenheit.

The welder should understand that if the oxidizing flame in the oxy-acetylene welding torch gives a temperature of 6300° F., then regardless of the size of the outlet, this same flame will still have a constant 6300° F. temperature. However, the heat generated from the larger gas outlet will increase as the gas outlet is increased. With this in mind it is understandable why heat is referred to as volume or quantity. For the purpose of heating a bar of steel as quickly as possible the welder would use a tip with the larger gas outlet.

GAS	B.T.U.	TEMPERATURE (with Oxygen)
Acetylene	1450	5850° F.
Natural Gas	1000	5306° F.
Butane	3300	5300° F.
Petrolene	3200	4570° F.

HEAT TRANSFER

RADIATION

Energy transmission in the form of rays or particles is known as radiation. Light and heat rays in the form of visible, infra-red and ultra-violet are radiated from the welding arc.

NOTE: Safety Precautions.

CONDUCTION

Heat conductivity is the transmission of heat from one part of the object to another part. The rate of conductivity varies with different materials, and this transfer is known as the Thermal Conductivity Rate.

The welder must have some knowledge of heat conductivity in order to compensate for expansion and contraction. He must be aware that the higher the thermal conductivity of the metal being welded the larger the volume of heat necessary to compensate for the heat loss in the surrounding areas, including the air.

Although aluminum melts at a lower temperature than mild steel, it becomes necessary to preheat the aluminum (especially in large size plates) due to the Thermal Conductivity being higher than that of the steel.

CONVECTION

This is a transfer of heat by an automatic circulation that occurs at a non-uniform temperature owing to the variations of density and the action of gravity.

The welder must be aware that transferred heat from one body to another can affect welding procedures.

EXPANSION AND CONTRACTION

When a metal is heated and dimensions are increased, the welding term used is expansion. When, on cooling, the metal is found to have resumed its original size, or some of its dimensions are found to have shrunk, used is the term contraction. A rise in temperature regulates the increase in the dimensions, and conversely contraction is regulated by the amount of temperature fall. Variation in the temperature of the parent metal when welding creates expansion and contraction problems. Some metals with low ductility, such as cast iron, could crack or fracture beyond as well as within the weld area.

The welder will, through experience, learn to cope with the ever present problems created by expansion and contraction. A change of dimension of a solid metal due to contraction can be described as upset, a phenomenon that facilitates the removal of broken studs from various castings etc., and will be explained in this section.

Distortion and Warpage created in ductile metals through expansion and contraction can be alleviated in many cases by:

(a) prebending and presetting.

(b) equalizing the pull by opposition welds.

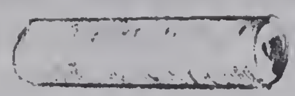
(c) "U" welds are used rather than "V".

(d) keeping down the number of passes and do not overweld.

(e) faster welding rate.

It will be noted in the illustration that when heat is applied at point (a), a ductile material such as an iron shaft will dish with the point of applied heat forming the bottom of the dish.

A



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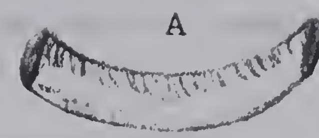
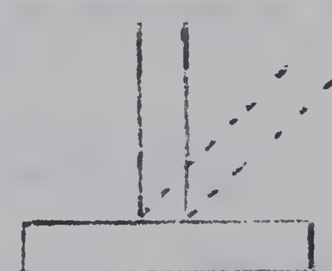


B

To overcome this problem a proper preheating procedure will help. Prebending and/or Presetting prior to heating, especially by an experienced welder, will alleviate the problem in many cases.

Therefore, Prebending prior to heating as shown in illustration (c) and Presetting as shown in (d) will help to overcome dimensional defects due to the distortion and warpage caused by welding heat.

C



D

In the above illustrations opposite welds or heat, applied alternately on opposite sides will equalize the pull effect.

If the number of passes are kept to a minimum, using a "U" or double "V" preparation, with a high welding rate, the problems created by expansion and contraction can be somewhat overcome.

Residual stress (internal stress) in a metal due to expansion and contraction will be prevalent when distortion and fracture has not taken place, and failure could result due to a slight dynamic stress. Failure will also result

where Expansion and Contraction of metals under extreme temperature changes have been restrained by mechanical means such as clamps or vises.

Expansion of metals are usually discussed under:

LINEAR EXPANSION

This is a noticeable increase in the length of a metal. It is the amount that a unit length of a metal rod expands when it is raised through one degree of temperature.

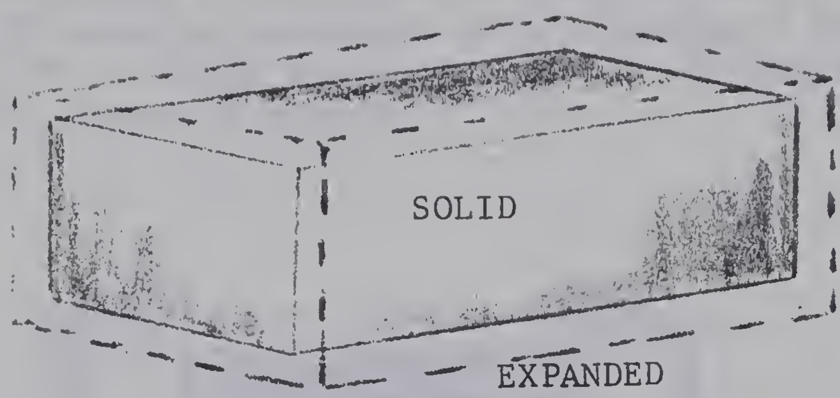
CUBICAL EXPANSION

This is sometimes called the volumetric Expansion where the volume of the metal is expanded. Three times the linear expansion is a guide to the cubical expansion.

COEFFICIENTS OF THERMAL EXPANSION OF METALS

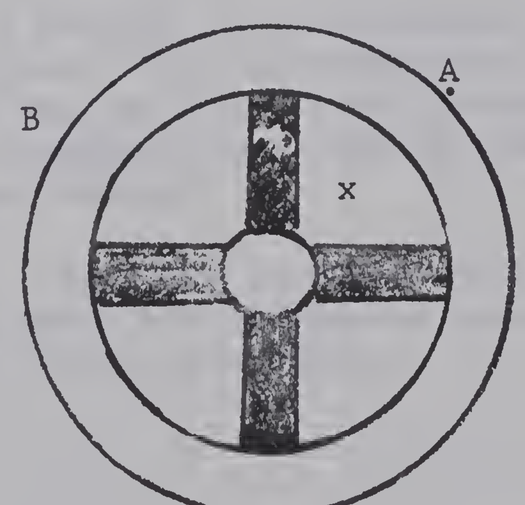
Metal	Coefficient	Expansion per Ft. Per Rise 1000 F.
Aluminum	0.00001234	0.148 in.
Copper	0.00000887	0.106 in.
Iron, Wrought	0.00000648	0.078 in.
Iron, Cast	0.00000556	0.067 in.
Nickel	0.00000750	0.083 in.
Steel	0.00000636	0.076 in.
Zinc	0.00001407	0.169 in.

A metal bar, on being heated, will, according to the previous terminology, have both linear and cubical expansion. If unrestrained, it will expand and contract throughout its volume, the amount dependent on the temperature. When cooled, the metal bar will have contracted to its regular size, measured prior to the heat application. This type of expansion and contraction is often referred to as Free Volumetric.

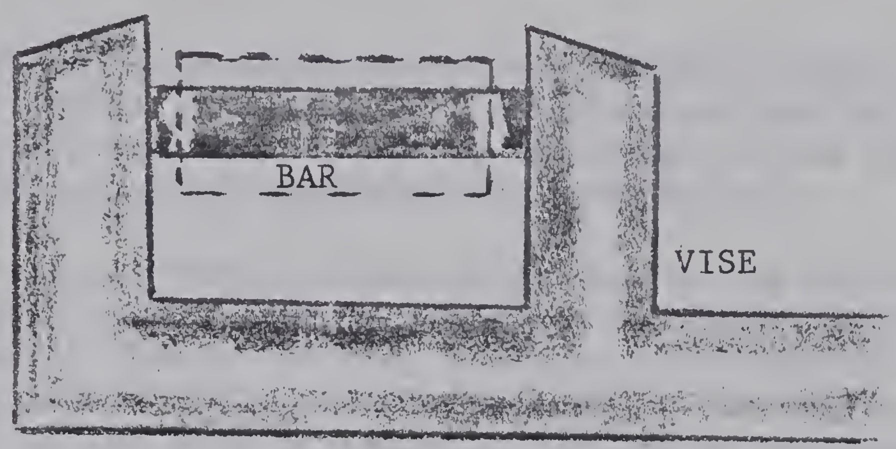


In the above illustration we recognize that prior to heating, and on cooling, the bar would take the form as shown by the solid lines. On heating, the bar would become larger, size depending on the temperature, and would take on the form of the broken lines.

Restrained expansion and contraction creates major problems for the inexperienced welder. When the expansion is re-strained, especially in all directions, residual stress is a factor to overcome especially in the more ductile metals. However, where warpage or distortion is prominent, the residual stress is somewhat relieved. In brittle materials cracking will take place in either the weld or other adjacent areas. Restricted contraction can also cause stress to such an extent as to distort areas surrounding the weld.



If the wheel on the previous page is cast iron, points "A" and "B" must be preheated before welding a prepared break at point "X" in order to compensate for the expansion and contraction creating stress.



The above illustration represents a bar where only one dimension is restrained. The bar, when heated, will expand only on the free dimensional sides. Since the cubical expansion in this case will be equal to the cubical expansion in a free expansion bar of the same size, heated at the same or equal temperatures, then we must assume that the free dimensions of the partially restrained bar will expand a great deal more to allow for the restraint on its other dimension.

However, on cooling, all dimensions will contract since contraction is free. The restrained expanded dimension, on cooling, is now smaller than it was originally, and therefore the other dimensions must now be somewhat larger since the volume is not changed.

Therefore, a bar held in a vise and heated would drop free on cooling since the restrained expansion dimension was free to contract and is now smaller.

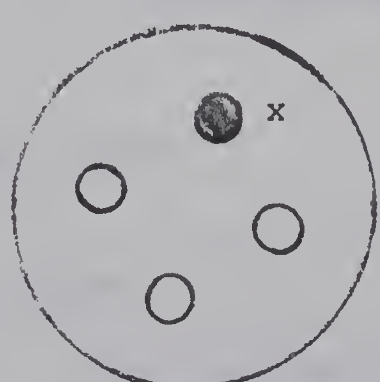
UPSETTING

This is a condition that is usually brought about when parts are heated at uneven temperatures causing a restraint of expansion in one or two directions and a free expansion in another direction.

Studs, bolts or other screw type adapters which have broken off within a casting or housing device can be removed by the welding operator by taking advantage of the free and restraining action of expansion and contraction.

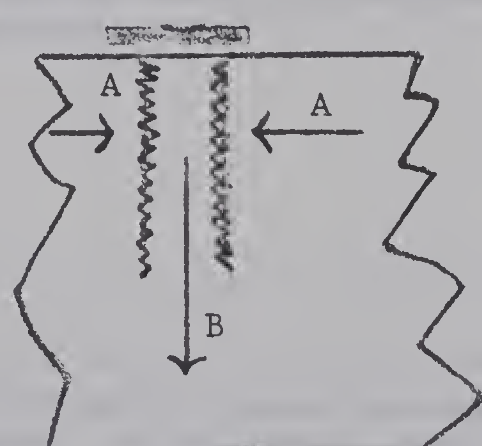
A nut placed over and fusion welded to the broken stud or screw type keeper creates expansion, through the 6000° F. temperature of the arc welding process. The internal threaded section restrains the expansion created by the surface circumference of the stud or keeper. The linear expansion, being unrestrained, expands to a greater degree to compensate for the overall cubical expansion which would take place if total dimensional expansion were free.

On cooling we have an unrestrained volumetric or cubical contraction which releases the keeper threads from the internal tapped thread section of the casting. By turning the nut, the now longer and thinner threaded keeper can be removed. Do not quench after welding as this procedure would cause a hard brittle material which could break when subjected to torque pressure for removal.



WHEEL HUB

X - Broken Stud



CROSS SECTION OF WHEEL HUB

A - Expansion Restrained

B - Expansion Free

NON FERROUS ALLOYS

ALUMINUM ALLOYS

Cast Alloys

These are alloys that are poured in a molten condition into sand or dies for the purpose of forming a desired shape when solidified. Die casting can be poured in a similar manner to the sand casting pour, but usually die casting is done under pressure to give a denser casting with a fine external finish.

Wrought Alloys

These are alloys which are designed to be worked mechanically, such as rolling, drawing and forging. Wrought alloys are available in shapes similar to steel. A digit system is used to designate wrought aluminum and its alloys, while the cast alloys usually have both a number and a letter system. This information is available through the manufacturers.

NOTE: Welding of aluminum can be accomplished by resistance, carbon arc, oxy-acetylene and inert gas methods.

COPPER ALLOYS

Brasses

Zinc alloyed with copper gives brasses. Zinc has a low boiling point and vaporizes very quickly and easily, and since it will volatilize from the brass puddle, it is important in welding to keep the heat as low as possible.

Bronzes

Copper alloyed with tin gives a more expensive metal than brass, known as bronze. Bronze, like brass, must not be heated to the boiling point, and if excess oxygen is present a strongly oxidizing flame is necessary. This oxidizing flame will be referred to in the next portion on Electrolytic Copper.

Monel

This alloy consists of copper and nickel, and when welding, a rod with a composition similar to the parent metal should be used. Stirring of the puddle should be avoided, and a carburizing flame is essential.

Copper-Silicon Alloys

Silicon, a deoxidizer for copper alloys, improves the mechanical properties of copper when used as an additive.

Everdur is placed in this class of alloy, and since most of the copper-silicon alloys have a lower thermal conductivity than copper they are less sensitive to heat. An oxidizing flame with a rod having the same characteristics as the alloy is used.

COPPER

This reddish-brown metal is very resistant to corrosion and oxidation. Although very ductile, copper has the quality of extreme toughness. Being similar to the metal antimony, in that it expands on solidification, copper is found very useful for manufacturing purposes. It alloys with about thirty different alloying elements, and because of the ease of multiple alloying, the properties and the usefulness of the alloyed metal is more extensive than it would be otherwise.

ELECTROLYTIC COPPER

Electrolytic copper oxides within a metal and can create problems in a finished weld if the proper procedures to eliminate the problems are not fully understood. The welder is well advised to forego welding, if strength is required, on any electrolytic copper as it contains from .01 to .08 percent oxygen which, being in the form of cuprous oxide, is scattered throughout the metal in the form of small particles.

DEOXIDIZED COPPER

As the name implies, this metal, unlike the electrolytic copper is free of oxygen. The welder should be aware of the high expansion rate of copper in order to overcome the problems mentioned previously. Moreover, copper leaves its solid form immediately on reaching its melting point and becomes a liquid. The heat conductivity of copper, being very high, creates a problem of heat dissipation within the parent metal itself and the air, which has been mentioned previously as conduction. Therefore, preheating must be considered.

QUESTIONS TO SECTION III

1. Which gives the greatest width of affected zone; electric or oxy-acetylene welding?
2. What does the percentage of carbon in steel determine?
3. What do you call steels that become relatively hard when cooled from their upper critical temperature in air?
4. How do you define metallography?
5. What are three (3) factors most important in the control of the structures of a piece of metal?
6. How would you describe ferrous metals?
7. Describe non ferrous metals.
8. What are three (3) ways used to recognize metals or alloys?
9. What is considered the most important alloying element of iron?
10. What are the four (4) classes under which carbon steels are divided?
11. Name three (3) types of Cast Iron.
12. What is the name given to internal stress?
13. What would be the reason for annealing steel?
14. What is the process known as tempering?
15. What type of steels are not recommended for flame hardening?
16. How can the critical temperature of steel be tested?
17. What are the two (2) operations in case hardening?
18. How does fine-grained steel compare with course-grained steel in strength?

19. How would you compare the homogeneous structure of cast steel and forged steel?

20. What are the names and percentages of alloying metals in tobin bronze?

WELDING

SECTION IV

PRINCIPLES OF ARC WELDING

Since welding is the uniting of metal into one strong homogeneous whole by the application of heat along the area of contact, then arc welding liberates heat at the arc terminals and in the arc stream, created by means of an electric current.

Arc welding can be presented to the student under the following:

CARBON ARC

The electrode in this process is of carbon or graphite which does not act as a filler metal in the fusion process, but creates the arc for the purpose of melting the metal. The carbon arc can be used in the cutting process which will be explained under Arcair Cutting.

METALLIC ARC

The material in this type of welding is a core of wire containing a low percentage of carbon. On coming in contact with the metal to be welded an arc is formed, which not only melts the parent metal but also melts the wire core rod which, on melting, mixes with the fluid parent metal as filler weld material. The metal is only melted at the point where the arc is struck on the plate.

SHIELDED ARC

During welding, the student must realize that oxygen and nitrogen from the air combine with the fluid metals wherever possible and form harmful oxides and nitrides which weaken the weld. The shielding of the arc will reduce this problem, and the various coatings on the rod or steel wire, known as flux, will create such a protective shield. Moreover, the type of manufacturing process of rod coatings is responsible for the differences in the strength of welding rods, even when the core wire has the same properties.

ATOMIC HYDROGEN

This is an arc process where the addition of hydrogen increases the heat output. The work does not need to be grounded during this process as the arc is formed by two fairly non-consumable tungsten electrodes.

All but the Atomic Hydrogen method of welding requires a type of closed circuit where the work is connected to one side of the circuit and the electrode to the other side. The power necessary to create heat for melting is measured by both voltage and amperes. The welding machines have easy adjustable amperage controls. The length of the arc and the diameter of the electrode govern the voltage. A long arc raises the voltage and lowers the amperage. A small electrode used to fuse light pieces of metal would require less current or amperage than a larger rod.

Current control is important in all welding procedures to ensure a steady constant travel speed of the electrode along both the lines of weld in order to deposit the filler metal, and downward to keep a constant arc length as the rod is consumed through melting.

VARIOUS TERMS AND DEFINITIONS

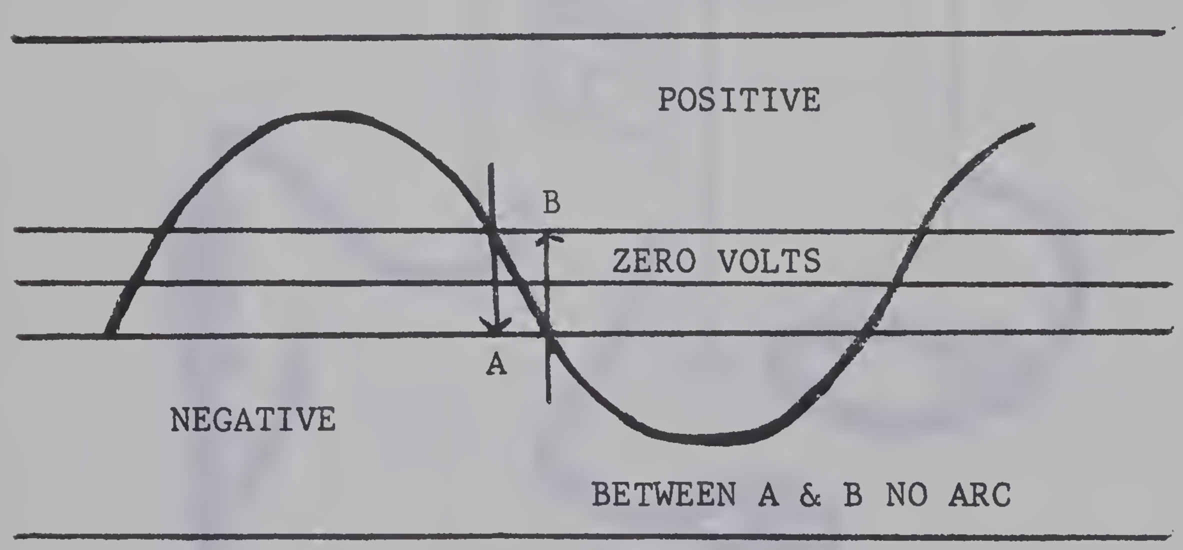
ALTERNATING CURRENT

In arc welding the power supply at the arc may be alternating current, the direction of which reverses at regular intervals according to the number of cycles of current being used.

With alternating current, carbon and bare electrodes were found to be unsatisfactory in the welding process since the polarity changed with every cycle.

Alternating current passes through zero value twice in every cycle, and if it were not for the speed with which the change takes place, the arc would go out at the points of zero value.

60 CYCLE ALTERNATING CURRENT



DIRECT CURRENT

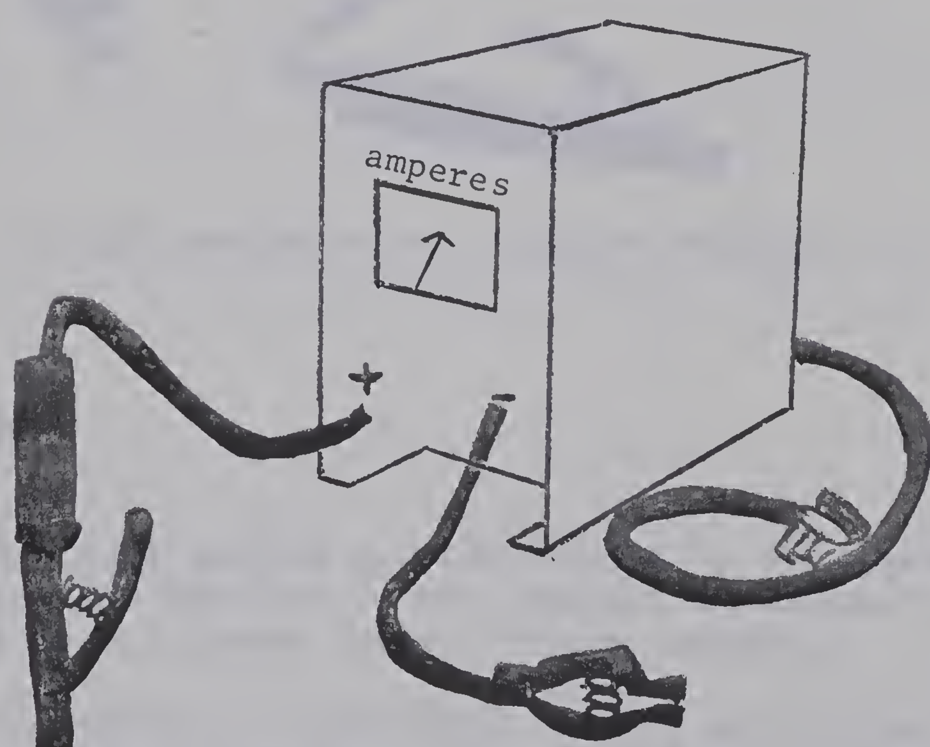
This is a current which flows always in the same direction. Unlike alternating current (where the polarity changes 120 times every second as with 60 cycle current) the Direct Current flows from the one pole continuously.

POLARITY

This is the quality of being attracted to one pole and repelled from the other. In Direct Current this polarity can be selected by changing welding cables on the terminals of the machine or by the use of a polarity switch. The two types of polarity are:

Reverse Polarity

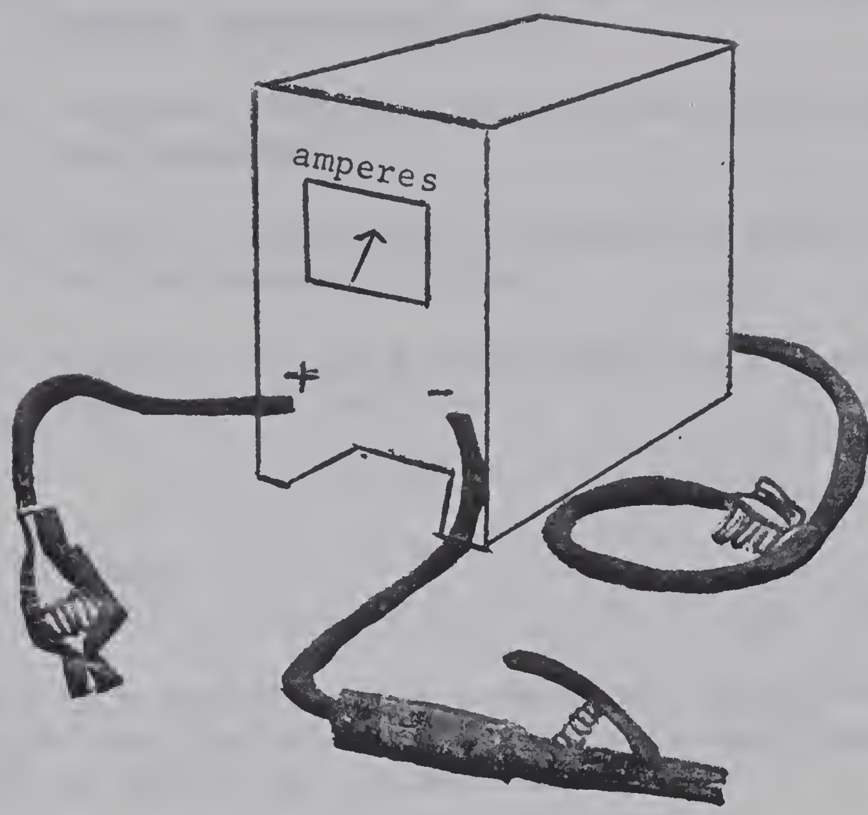
The electrode cable for this polarity is attached to the Positive Terminal (+) and the ground clamp cable to the Negative Terminal (-).



CABLE ATTACHMENTS FOR REVERSE POLARITY

Straight Polarity

For this type of polarity the cables will be reversed on the terminals if set for reverse polarity as above. The student must be aware that removal of welding cables from the terminals will not be necessary on the type of welding machines having a polarity switch.



CABLE ATTACHMENT FOR STRAIGHT POLARITY

ARC BLOW

This is a welding problem created by the magnetic fields set up in the work due to the constant directional flow of current from a Direct Current Welding machine.

Long periods of continuous welding at high heat will usually create a problem. The molten metal from the rod reacts to these magnetic fields in such a manner that only after the problem is rectified can the arc be controlled so that metal can be deposited in the required area.

Corrective Steps:

(1) Use an A.C. machine where current flow reverses uniformly and will therefore be unable to set up magnetic fields.

(2) Reduce the Current and change the position of the ground clamp on the work.

(3) Weld the corners first and use a back step welding procedure.

(4) Wrap the ground cable around the work to counteract the magnetic field.

(5) Continue to use a very short arc and weld towards a heavy tack weld.

TENSILE STRENGTH

This is a resistance of a material to the forces of rupture on longitudinal stress, which is expressed in thousands of pounds per square inch (psi.)

Bare electrodes, coated rods and low alloy high strength electrodes can deposit weld metal having varying differences in tensile strength and yet the core wire could come from the same spool.

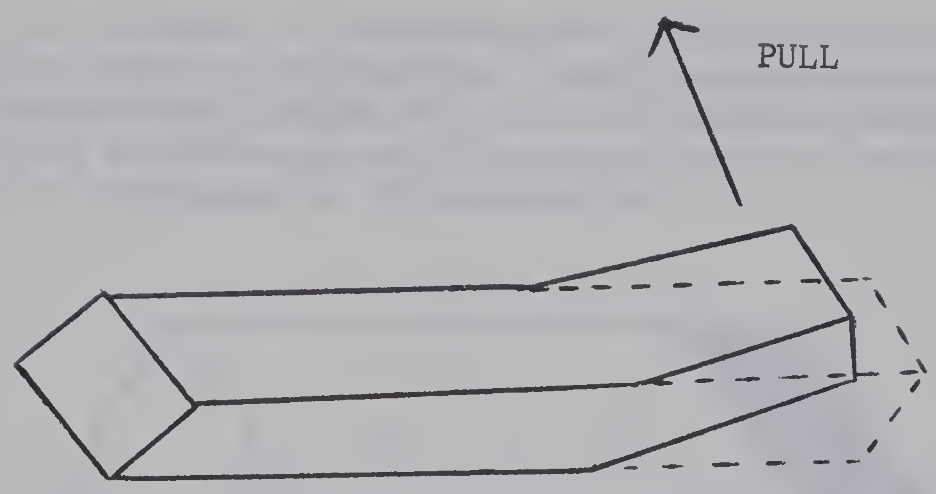
This difference in tensile strength is possible through the manufacturing process of the flux coating on the rods which contain powdered metal particles or other metallic alloying elements.

This core wire of low carbon rimmed steel would consist of not more than .15% carbon and 99% iron with the balance usually consisting of manganese, sulphur and phosphorus.

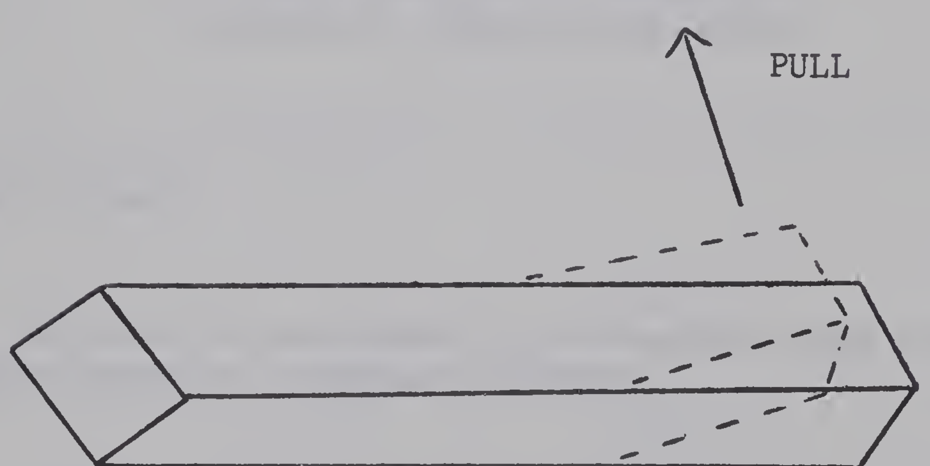
DUCTILITY

Any metal that can be bent or deformed in any direction without failure is said to be ductilte if the metal remains permanently deformed. A spring will bend but will not remain in the bent position and is usually low in ductility.

NOTE: Usually when Tensile Strength goes up then the Ductility of a metal goes down.



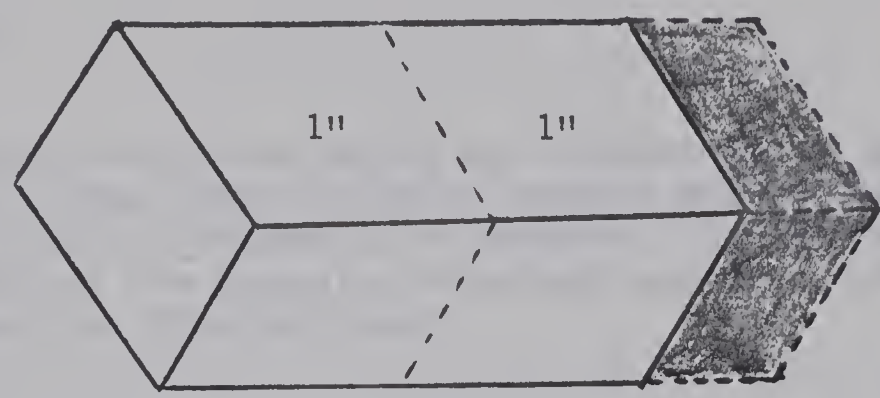
SOLID LINE - MILD STEEL BAR AFTER DISTORTION



SOLID LINE - SPRING AFTER RELEASE FROM PULL

ELONGATION

The addition or extension that adds to the length of metal is known as elongation. Ductile metals are measured as a percentage elongation. If a 2" piece of metal is stretched or deformed to 2½" without failure the ductility would be expressed as 25% elongation.



SOLID LINE - 2" ORIGINAL METAL
½" SHADED PORTION IS EXTENSION
UNDER PULL PRIOR TO BREAKING

ELASTIC LIMIT

This can be expressed as the maximum load a metal will support before it begins to stretch.

YIELD POINT

Any load measured in pounds per square inch which increases the deformation of a material without an increase in load can be classed as yield point. Steel, being flexible, has a definite yield point.

PENETRATION

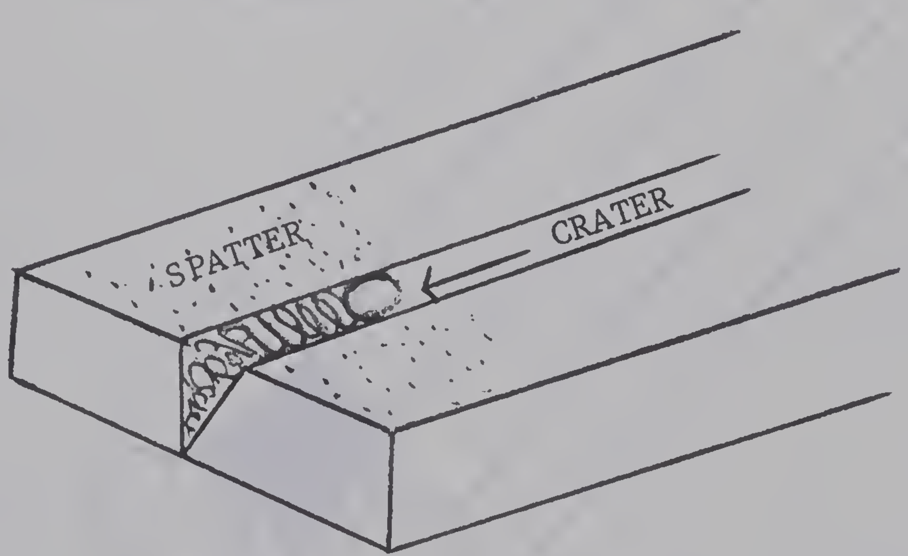
This is also called depth of fusion and is the distance from the surface of the parent metal to the point at which fusion has ceased. Since it will vary with the amount of heat at the arc, it has been referred to as Arc Force.

SPATTER

Molten metal lost during arc welding due to problems creating a fine spray and which creates what is known as spatter loss is referred to as spatter. The difference in the weight of the deposited electrode and the melted electrode would be "Spatter Loss".

CRATER

This is the depression left at the end of an arc weld or when the arc is broken.



UNDERCUT

This is an unfilled crater left in the base metal, usually at the side of the weld created due to one or all of the following reasons:

(1) Too high of a welding heat.

(2) Too fast a travelling speed.

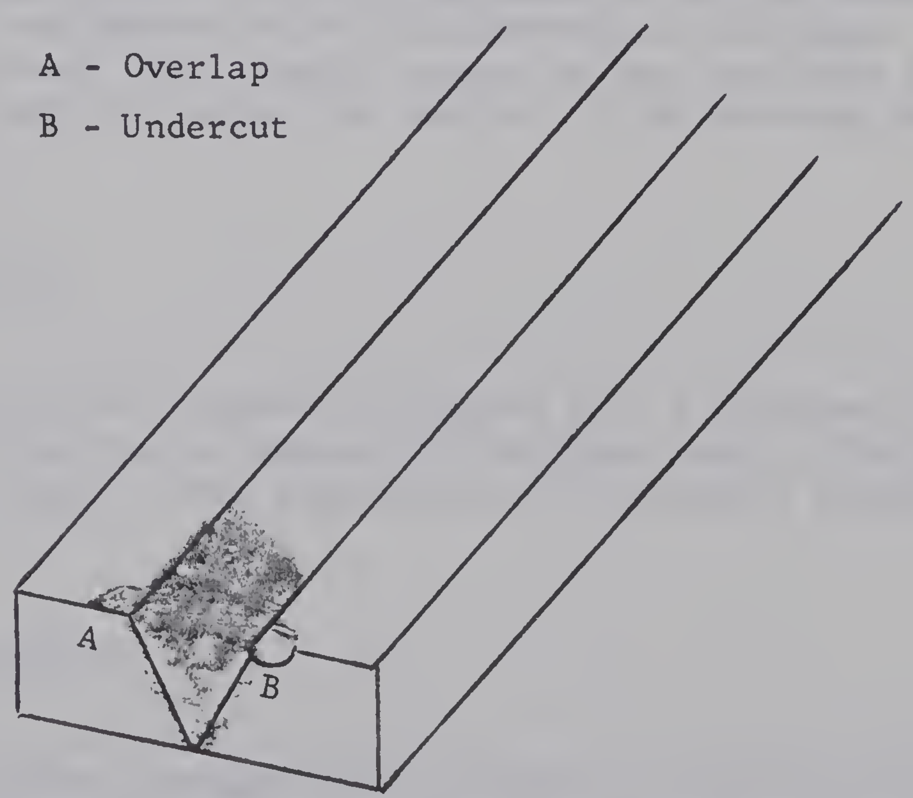
(3) Wrong application for depositing metal.

OVERLAP

Any weld metal which extends over and beyond the limits of fusion at the toe of a weld is called overlap.

A - Overlap

B - Undercut



IZOD IMPACT

This is an impact test which gives a guide to the resistance to failure at a discontinuation and also gives a guide to the resistance of a material during extension of a crack. The resistance is expressed in foot pounds.

HARDNESS

Hardness is the resistance, tested by either the Brinell or the Rockwell method, of the depth of penetration of an object on some material under pressure.

STRINGER BEAD

The molten metal is deposited without side motion in the stringer bead weld. The only movement is in the direction of travel and downwards as the electrode is consumed. The speed of travel, arc length, amount of heat and size of the electrode will determine the contour of the stringer bead.

STRINGER FILL

This is a weld which is blended into a finished weld contour by the use of successive stringer beads. The parent metal has usually been prepared for this type of welding.

STRINGER PADDING

Successive stringer beads applied to the previous bead are used in some cases for weld build-up purposes and known

as Stringer Padding. Each bead is fused into the previous bead in such a manner as to make the top surface as level as possible.

This procedure in building up a surface will, if applied properly, reduce warpage. Where build up by means of stringer padding is done in the flat or down hand position, it is necessary to deslag each bead before proceeding with the next bead application. If the build up is applied in the horizontal position and the bead application starts at the bottom of the surface to be built up, gravity will take care of the flux problem and deslagging will not be necessary.

WEAVE BEAD

This is a bead made using the same procedure as the stringer bead with additional side movement of various acceptable weaving motions. The heat input is greater with this method than in the single bead method which retards the cooling rate in the weld area. The side motion of the electrode should be kept to a minimum where smooth finished welds are required.

WEAVE PADDING

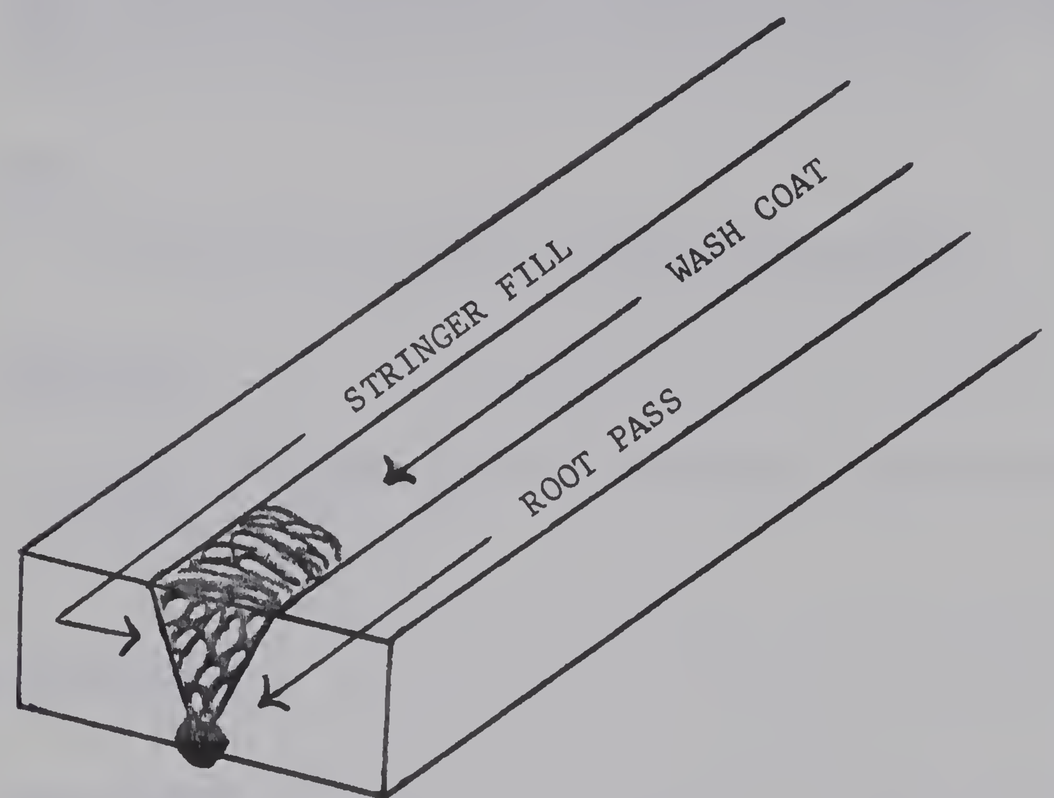
When weave beads are blended to build up worn surfaces in a similar manner to stringer padding, it is known as Weave Padding.

FILL PASS

Where the metal to be welded has been prepared, the welder will deposit filler metal after the first pass by means of a stringer or weave bead which is commonly called the Fill Pass. More than one fill pass can be used followed by a cover pass.

ROOT PASS

This is the first stringer bead made at the root of the weld and is sometimes referred to as the penetrating pass.



FINISH PASS

This is a form of fill pass which is deposited as a heavy pass for the purpose of not only filling the prepared groove in the parent metal, but at the same time completing the surface weld.

WASHCOAT

This is also referred to as a Cover Coat since it is applied to produce a good finish over the preceding fill passes.

ELECTRIC WELDING CIRCUITS

VOLTAGE

The voltage between the electrode and the parent metal forms the arc stream voltage which, through pressure drives the electrons across the arc and is responsible for the effective metal flow in the weld.

VOLT

The volt is a unit of electrical pressure.

VOLTMETER

This instrument shows the voltage or pressure in a circuit.

TYPES OF VOLTAGE

ARC VOLTAGE

As explained previously, this is the voltage between the welding rod and the work at the time the arc is struck. Arc Voltage will not remain constant but will rise and fall during welding. The drop in voltage is not only due to the arc fluctuation but also due to resistance of the leads.

OPEN CIRCUIT

When the welding machine is running and no welding is being done the voltage between the terminals of the welding source is Open Circuit.

NOTE: In arc voltage the amperage increases and the voltage decreases while the opposite is true in open circuit voltage.

AMPERE

Amperes are present in a circuit along with voltage and are the electrical units for the rate of flow through this circuit. In direct current circuits the product of volts and amperes represent the amount of electrical energy flowing through the circuit. The amount of penetration during welding is dependent on the amperes.

TYPES OF ARC MACHINES

The arc welder is a machine which produces welding currents within the limits necessary for arc welding.

(1) A. C. TRANSFORMER

A machine constructed with no major moving parts, and capable of delivering high amperage and low voltage suitable for welding purposes.

The advantages of these machines are the low maintenance and low initial purchase costs. As mentioned under arc blow, the A. C. will not set up troublesome magnetic fields.

(2) RECTIFIER WELDERS

These machines are suitable for both manual and automatic welding. Smoother metal transfer through the arc in all positions is accomplished with this type of machine. These machines are available in the combination A. C./D. C. unit. The welding units are built with either a selenium or a silicon rectifier which will convert alternating to direct current.

The rectifier welders are reasonable in price, and the operational costs are low. They operate

quietly with all types of electrodes with a variety of voltage ranges. The major moving part on this type of welder is the fan, so necessary for cooling purposes.

(3) A. C. GENERATOR

These machines are in a higher price bracket than the A.C. Transformer type, and since the current is produced by means of a generator, they are noisier and the upkeep is naturally more costly.

The machine is available electrically driven or with a gasoline motor for portable purposes. Arc blow problems are not encountered when using this type of machine in the high heat range over long periods of time.

(4) D. C. GENERATOR

This is a direct current generator where the principle of a rotor turning within magnetized fields createsthe current which always flows in the same direction. The machine can be gasoline or electric driven. The initial price of this type of a welder, as well as the operating and upkeeping costs, must be considered when comparing with generator welders for equipment purchases.

NOTE: Engine-driven welders, when compared with transformer types, are not as favorable where critical welding under closely controlled conditions is a necessity.

When an arc is struck on an engine-driven welder the voltage output goes from 60 volts to 70 volts open circuit to zero voltage before establishing arc voltage. The interval between these changes is so short that the rotating parts of the generator cannot compensate for the inertia set-

up by the part which creates a delay in the arc stabilization. For general welding this problem does not create any noticeable unfavorable condition.

BASIC ELECTRIC WELDING PROCEDURES

Since various types of welding machines, fluxes, electrodes, along with the common welding terms have been covered, various methods in which these tools can be adequately used will now be presented.

ARC STRIKING

The welding current does not start until the electrode makes contact with the work which previously has been mentioned as arc voltage. If, on touching the work, the electrode is not quickly removed, it will weld to, or as is more commonly known, freeze to the work.

To produce a weld the electrode must be removed from the parent metal, a distance of not more than the diameter of the core wire in the electrode. This will create what is known as the correct arc length. If the electrode freezes, the student should release the holding clamp on the electrode holder, and then remove the electrode from the work by a twisting motion.

The two procedures for striking an arc are the tapping method used on D. C. machines and the match scratching method used usually on the A. C. type.

RUNNING BEADS

When the amperage is set properly and the arc length well established, the molten metal from the electrode and

the metal to be welded should fuse smoothly with the current giving off a sharp cracking sound similar to bacon frying.

Welding in flat position, bead technique only, should be the student's first attempt. Uniform speed forward and electrode feed in a downward motion to compensate for the rod consumption, once accomplished, will make the additional movement of weaving easier when attempted.

At this time the student is well advised to learn the proper techniques for various rod inclinations. The flat and overhead position welding is applied with the same rod inclination technique; the electrode is held from 75° to 90° to the metals to be welded and in the direction of welding as illustrated.

Bead contour is important for strong uniform welds, and only through practice can undercut, overlap and spatter be recognized and overcome.

PROPER BEAD CONTOUR

WEAVE WELDING

When the student has corrected the short-comings of bead welding through continuous practice, the technique of weaving is accomplished with less effort and practice.

The first practice weave should be a simple 90° back and forth motion to the weld direction or line of weld. The back and forth motion should not exceed more than three times the diameter of the electrode being used. A slight hesitation before the return motion of the weave will assure a sound, smooth weld with no undercut or unfilled crater.

BUTT WELDING

When two pieces of metals are to be butt welded, preparation as described in Section II Page 34 can be used, especially on materials over 3/16" thick. These preparations can be made by using the oxy-acetylene cutting torch or grind stone. The student may use any of the filler metal processes mentioned previously. A wash or cover coat weaved in the manner described in the various reference books should be practiced and the most successful method applied.

TEE JOINTS

For these joints the butt joint electrode inclination is not satisfactory. In the tee joint a fillet weld must be placed on both sides of the upright for strength. The electrode must always be inclined in such a position as to divide the plate angle, but at the same time, the 75° angle in the direction of the weld, as in flat welding, must still be adhered to. The bead would be the initial metal fill or first pass followed by the necessary successive weave passes. Information on fillet welds should be reviewed before welding.

LAP JOINTS

These joints, like tee joints, can be made in the flat, horizontal or vertical position. The electrode inclination in any vertical weld joint should remain as near to 90° as possible.

As with the tee joint welds, the inclination of the electrode in the lap joint should also divide the plate angles equally. The only exception is where plates in the lap are of unequal thicknesses, where the rod would then incline towards the heavier plate. Whenever a plate in the lap or tee joint shows undercut, the problem can only be overcome by welding with the electrode inclined toward the undercut.

VERTICAL, HORIZONTAL AND OVERHEAD WELDS

This type of welding is more difficult than flat and requires more skill through practice. Molten metal tends to fall or drip in the above positions due to gravity. Current control and a close arc is most essential when welding in these positions. Welding upwards from the bottom in the vertical plane is not easier but should be completed in this manner especially on heavy materials. Light materials can be welded in the opposite direction faster and more satisfactorily if the low penetration electrode is used.

Electrode weaving for fill or finish passes should be held close to the work at the proper angle with a slight hesitation at each edge of the weave.

LAP

PIPE

ROD INCLINATIONS

WELDING ELECTRODES

Welding rods and welding electrodes are usually referred to as meaning the same thing. Usually we refer to the filler metal in the oxy-acetylene welding process as a filler rod with the electrode referred to as the filler metal in the electric welding process.

COATED ELECTRODES

These electrodes have a flux applied to the wire by spraying, painting, dipping or other methods. The purpose of the flux is to unite with impurities in the fused metal and float them away as a slag or gas. The oxides and nitrides which reduce the strength of a weld are excluded to some extent by a short arc, but a flux added to the rod further protects the metal with a gaseous shield.

Flux not only takes out objectionable elements but adds new ones so necessary for strong welds. The weld speed is increased by the flux, and the cleaning action is also beneficial to sound finished products.

TYPES OF FLUX COVERING

(1) High Cellulose Content

Electrodes have rapid burn-off and deep penetration with this type of flux. Welds are made in all positions but usually for vertical-down on pipe and structural work. Usually the rods with this type of flux are used on a D. C. welder with electrode positive polarity.

(2) Titania Content

The flux containing titania (as a rutile) makes welding easier. The molten metal is supported by a viscous slag suitable for vertical and horizontal fillet welds.

(3) Titania and Basic Compounds

Flux containing titania and added basic compounds are similar to the one above but have a more fluid slag which gives a smooth arc with medium penetration which is suitable for all position welding. The above two types of flux electrodes can be used on A. C. or D. C. welders with either polarity.

(4) Manganese, Iron and Silicates

This flux consists of oxides or carbonates of manganese, iron and silicates which makes for easy slag removal. The electrodes containing this flux are used in the downhand position usually with the electrode positive polarity.

(5) Iron Oxide Content

Iron oxide flux will give a low penetration which results in lower tensile strength, but the results produced are smooth in appearance.

(6) Calcium Carbonate Fluxes

This is a low moisture content flux consisting of calcium carbonate and floride as limestone and fluorspar. These are the low-hydrogen electrodes so popular in the welding of high carbon or sulphur steels. The flux must be kept dry, and when iron powder is added, higher heats are possible with the smaller core electrodes.

KEY TO ELECTRODE IDENTIFICATION

The American Welding Society (AWS) establishes classifications for various types of electrodes. Usually, an electrode is classified in only one classification, even though it may meet the requirements of several other classifications. AWS allows certain exceptions and where such is the case, both classifications are given.

The National Electrical Manufacturers Association (NEMA) establishes color codes ("E", "S" and "G" above) which are painted on the electrodes to distinguish the various types.

Not all types of electrodes have classifications or color codes. Some types have color codes, but not classifications. In some cases, there are two different electrodes which have the same classification, color code and coating color.

AWS NUMBERING SYSTEM

Prefix "E" stands for electrode--designates arc welding.

In mild and low alloy steel electrodes:

First two digits of four digit numbers and first three digits of five digit numbers indicate tensile strength:

E60xx	....	60,000 psi Tensile Strength
E70xx	....	70,000 psi Tensile Strength
E80xx	....	80,000 psi Tensile Strength
E90xx	....	90,000 psi Tensile Strength
E100xx	....	100,000 psi Tensile Strength
E110xx	....	110,000 psi Tensile Strength

Next-to-last digit indicates position:

Exx1x	....	Indicates all positions
Exx2x	....	Indicates H-fillets or flat
Exx3x	....	Indicates flat position only

The last two digits together indicate the current to be used and the type of coating:

Exx10	....	Organic--DC + only
Exx11	....	Organic--AC or DC +
Exx12	....	Rutile--DC--or AC
Exx13	....	Rutile--AC or DC--
Exx14	....	Rutile, Iron Powder (approx.) 30%)--AC or DC ±
Exx16	....	Low Hydrogen--DC + or AC
Exx18	....	Low Hydrogen, Iron Powder (approx. 25%)--DC + or AC
Exx20	....	High Iron Oxide--DC ± or AC
Exx24	....	Rutile, Iron Powder (approx. 50%)--AC or DC ±
Exx27	....	Mineral, Iron Powder (approx. 50%)--AC or DC ±
Exx28	....	Low Hydrogen, Iron Powder (approx. 50%)--AC or DC +

ELECTRODE

ELECTRODE SELECTION

Job requirements are the basis of electrode selection. Look the job over carefully to determine just what the electrode must do.

Within the selected group, choose an electrode that has the physical properties and operating characteristics you need. Then check the special characteristics of other electrodes in different groups to be sure you've considered all possible choices. If more than one electrode appears equally suited for your work, try them on the job. One will reveal its superiority for your application based on:

(1) Properties of base metal.

(2) Position of the joint.

(3) Type of joint.

(4) Amount of weld required.

(5) Tightness of fit-up.

(6) Type of welding current available.

FAST-FREEZE (E6010 and E6011)

These rods have the ability to deposit a weld which solidifies--or freezes--rapidly. This is important where there is some chance of slag or weld metal spilling out of the joint,

as when welding vertical or overhead joints. Structural steel erection and pipe welding are typical examples, while some sheet metal welds are exceptions. General purpose welding is widely done with these electrodes, particularly when most of the work is out-of-position or is dirty or greasy. Deep penetration and light slag produce best possible results under these adverse conditions.

Joints requiring deep penetration, such as square edge butt joints, are welded in the flat position with the larger sizes of these electrodes. Galvanized steel is best welded with these electrodes because the forceful arc bites through the galvanizing and the light slag reduces bubbling and prevents porosity. Sheet metal edge and butt welds on 10 to 18 gauge steel are welded with these electrodes using straight (electrode negative) polarity. This produces a fine spray type arc which has little penetration and provides excellent fast follow ability.

FAST FILL (E6024, E6027, E7024)

The above rods have the ability to deposit metal rapidly. It might be considered the opposite extreme of fast-freeze and is the most outstanding characteristic of this group of electrodes. (E6024 and E7024) are heavily coated iron powder electrodes. They have high deposition rates, produce exceptionally smooth beads, and have a thick dense slag which tends to peel off the weld. Operating characteristics are the principal distinguishing characteristics between the two electrodes. Small sizes (1/8" - 3/16") of E6024 and large sizes (7/32" - 5/16") of E7024 have faster speeds, higher deposition rates and smoother arc action than their counterparts. By contrast, small sizes of E7024 and large sizes of E6024 have greater arc force, better control of molten pool under conditions of arc blow or when work is positioned downhill, and flatter bead shape. (E6027) also has a heavy iron powder coating and high deposit rates. Bead appearance is excellent, though not quite as smooth as the above. Its slag is crumbly and removes easily from any joint. The E6024 electrodes penetrate lightly so there is little pickup of alloy from the base metal. Their deposits are high strength and approach those of low hydrogen electrodes in crack resistance.

FILL-FREEZE (E6012, E6013, E6014, E7014)

"Fill-Freeze" is the name given the above group of electrodes which combine in some degree both fast-freeze and fast-fill characteristics. There is considerable difference within this group: Some electrodes are principally fast-fill with little fast-freeze; others have less fast-fill and considerably more fast-freeze. Several electrodes within the Fill-Freeze group exhibit another unique characteristic called "Fast Follow." Fast-follow is the ability to deposit a small bead on 10-20 gauge sheet steel at high speeds without skips or misses.

(E6012), used in all positions is a reliable general purpose and production electrode and has a forceful arc. (E6012) has iron powder to provide exceptional deposit rates and operates well on AC. Excellent for low current applications because it resists sticking. (E6012) has a smooth and steady arc with minimum spatter and easy slag removal. (E6013) provides excellent AC operation which is softer, steadier and has less sticking than E6012 electrodes; but is somewhat slower. Widely used on sheet metal when appearance and ease of operation are more important than speed. Also used for general purpose welding with the smaller, limited input, low open circuit voltage on AC welders. (E6014 and E7014) has iron powder which provides best fast-fill ability of all electrodes in this group. Exceptional operator appeal and the principal application is one production welding of irregular shaped parts where some downhill work is encountered. Vertical-up procedures are preferred for vertical joints.

Joints with poor fit-up can be welded with these electrodes when fast-fill electrodes, which would be used with good fit-up, tend to spill through. General purpose welding is a common application for these electrodes, particularly when it is desired to use only one or two electrodes for all welding jobs. High-speed lap and fillet welds on 10 to 20 gauge material are welded with these electrodes. On these applications fast-follow ability becomes important.

LOW HYDROGEN (E6018, E7018, E6028, E7028)

"Low hydrogen" is a term used to describe electrodes which have coatings that contain practically no hydrogen. These electrodes produce welds that resist underbead and micro-cracking and have exceptional ductility. They simplify welding procedures on hard-to-weld steels and alloy high tensile steels by reducing preheat requirements. The welds have high ductility, and porosity is eliminated in welds on sulphur bearing steels.

E7018 and E6018 electrodes also meets the requirements of E7016 and E6016 electrodes, and are for out-of-position work. Iron powder in its coating provides highest deposit rates consistent with out-of-position operation. The E7028 and E6028 electrodes have a high iron powder content which provides deposit rates and operator appeal of Fast-Fill electrodes while retaining the quality of low hydrogen deposits. The slag cleans easily, and they are principally used on flat and horizontal welds.

Welds are made satisfactorily on all types of joints on hard-to-weld and high tensile steels, including out-of-position work. The use of a low hydrogen electrode reduces or eliminates the need for preheat on carbon or alloy steels, produces porosity-free welds on high sulphur steels and eliminates hot-shortness on phosphorous bearing steels.

ELECTRODE WELDING PROCEDURES

MILD STEEL ELECTRODE PROCEDURES

E6010 - This electrode should be used on D. C. reverse polarity.

E6011 - This electrode is highly rated on A. C. machines but on D. C. reverse polarity it also works well. The current should be reduced 10% from that used on the A. C. machine setting.

In the flat position a close arc with a travel speed fast enough to stay ahead of the molten pool is required when using the above electrodes.

The vertical position gives better penetration when a vertical-up weld is made. Vertical down gives faster welding, and for this reason, pipeliners use the down method. For vertical-up the first pass should be a stringer bead made with a whipping motion for fillet welds and a circular motion for vee-butt joints.

Overhead and horizontal butt welds can be best made with stringer beads with the vertical technique of application.

E6012 and E6013

These electrodes use DC (–), straight polarity for best performance on all applications except those where arc blow is a problem. In cases of arc blow, use AC.

On downhand and downhill use stringer beads for first pass except on joints with poor fit-up where a slight weave is better. Use either stringer or weave beads for succeeding passes, and hold a 1/8" or shorter arc. Tip the holder in direction of travel and move as fast as possible, consistent with desired bead size. Use currents in middle to higher portion of range.

In vertical-down welding use stringer beads or slight weave and make small beads. Tip holder down so arc force pushes molten metal back up the joint. Move fast enough to stay ahead of molten pool, and use currents in higher portion of range.

When welding vertical-up use wide triangular weave, and weld a shelf at bottom of joint and add layer upon layer on it. Do not whip or take electrode out of molten pool, but point electrode slightly upward so arc force assists in controlling the puddle. Travel slowly enough to maintain the shelf without spilling, and use currents

in lower portion of the range.

In overhead welding use whipping technique with a slight circular motion in the crater to make stringer beads. Tip holder slightly forward, and use a short arc, fast enough to avoid spilling, with the currents in the lower portion of the range.

When welding sheet metal, weld vertical-down when possible and tip the holder forward in the direction of travel. Move as fast as possible while maintaining a continuous bead, and use currents in middle to higher portion of range.

E7014

This is an all position, high speed iron powder electrode which can be used with either the drag or free arc techniques. This electrode features exceptionally easy slag removal with very low spatter loss. It is used for many out-of-position applications and particularly for vertical-down.

Because of low spatter loss and the substantial addition of iron powder through the coating, higher current rates on production work with improvement in welding speeds is made possible.

This electrode may be used on A. C. or D. C. and either polarity. On thin materials, straight polarity on a D. C. machine is preferred especially for the fillet or lap welds. A higher inclination angle can be used on fillet welds to alleviate the problem of double beading.

E6024, E6027 and E6074

With these rods AC produces best speeds and operating characteristics. DC (+) may also be used, though it promotes arc blow and complicates control of the molten puddle.

When welding in the flat position use a drag technique and deposit stringer beads. The electrode should be held perpendicular with the holder tipped forward about 30° into the direction of travel.

In horizontal fillets and laps use a procedure identical to that given above, except that one points the electrode into the joint at an angle of 45° with the horizontal instead of holding it perpendicular. The holder is tipped forward about 30° as above, and the tip of the electrode must touch both horizontal and vertical members of the joint.

E6018, E6028, E7018 and E7028

These low hydrogen electrodes must be kept dry. Either they should be used promptly as they are taken directly from freshly opened containers or they should be stored in a warm, dry place. Otherwise, they will pick up moisture from the atmosphere and lose some of their low hydrogen properties. These rods may be used with alternating or direct current, reverse polarity. Use the maximum amperage within the recommended range that the job will permit and always maintain a short arc to keep atmospheric gases out of the molten metal.

On downhand, drag the electrode lightly or hold a 1/8" or shorter arc. Do not use a long arc at any time, since this type of electrode relies principally on molten slag for shielding. Stringer beads or small weave passes are preferred to wide weave passes. When starting a new electrode, strike the arc ahead of the crater, move back into the crater and then proceed in the normal direction. Use lower currents with DC than with AC. Point electrode directly into joint and tip holder forward slightly in direction of travel. Govern travel speed by the desired bead size.

For vertical, weld vertical-up with 1/8" or 5/32" sizes and use a triangular weave. Build a shelf of weld metal and, with the weave, deposit layer upon layer of metal as the weld progresses up the joint. Do not use a whip technique or take the electrode out of the molten pool. Point the electrode directly into the joint and

slightly upward to permit the arc force to assist in controlling the puddle. Travel slow enough to maintain the shelf without causing metal to spill. Use currents in lower portion of range.

In overhead, use a 1/8" or 5/32" size electrode with a slight circular motion in the crater. Maintain a short arc. Motions should be slow and deliberate. Point electrode directly into the joint and tip holder slightly forward in the direction of travel. Move fast enough to avoid spilling weld metal, but do not be alarmed if the slag spills some. Use currents in lower portion of range.

STAINLESS STEEL

Stainless steels are grouped in two general categories, straight chromium and chromium-nickel.

A. STRAIGHT CHROMIUM TYPES

(1) Ferritic Chromium

The ferritic chromium steels have a low carbon content in comparison with their chromium content, so they have a ferritic structure at room temperature, and when these alloys are heated, they are essentially non-hardenable by heat treatment.

When heated to the high welding temperatures all ferritic chromium stainless steels are susceptible to an embrittlement and loss of corrosion resistance. The result is a large-grained weld zone which is relatively soft, but brittle. The grain size remains coarse even after this annealing although the brittleness can be removed.

(2) Martensitic Chromium Grades

The martensitic chromium alloys behave like an alloy steel with high hardenability. When they are heated, austenite is formed. During rapid cooling the austenite is transformed into hard and brittle martensite. These alloys can be heat treated to a specific hardness as required for each application.

The hardness of martensitic chromium stainless steel increases as the carbon content increases. As hardness increases, the tendency for cracking as the weld cools is also increased. To control the tendency for cracking, pre- and post-heating are often required.

B. CHROMIUM-NICKEL TYPES

The chromium-nickel steels are so alloyed that the austenite is stable at room temperature. Since the austenite does not transform when the steel is cooled, these alloys cannot be hardened by heat treatment. Because the austenite is tough and ductile in the as-welded condition, the chromium-nickel grades are the most suitable for welding. No annealing is necessary.

The chromium-nickel types consist of:

(1) The extra low carbon grades with a maximum carbon content of .03% carbon.

(2) The stabilized grades containing either titanium, columbium or a combination of both. They are more corrosion resistant than the low carbon grade especially for continuous service.

(3) The high manganese grades which are basically 18-8 type austenitic stainless steels with a higher content of manganese than nickel.

(4) Molybdenum grades which are used to aid the corrosion resistance against chemicals.

STAINLESS STEEL ELECTRODES

Excellent welds are made in most grades of stainless steel using relatively few standard electrode types. Generally, a higher alloy content means higher corrosion resistance. Therefore, the properties of the base metal are often exceeded by welding with an electrode of higher alloy content. The high heat of welding sometimes causes changes in the base metal which seriously reduces ductility or corrosion resisting properties of the metal.

The use of an electrode of a type of stainless steel other than that of the parent metal will sometimes eliminate the need for costly heat treatments before or after welding. Special rods to match the characteristics of most stainless steels are available, but for the majority of welding jobs left to the general welder, these can be satisfactorily performed with the general type of electrode for stainless steel purposes.

These electrodes are available with the lime type or the titania type coating. The lime type coated electrode is used with D. C. reverse polarity while the titania coated type can be used with either A. C. or D. C. reverse polarity.

Lime Coated

These electrodes give the best penetration and operate satisfactorily in all positions. Welding vertical-down, the smaller type of electrode is found to be satisfactory.

Titania Coated

These are the A. C. - D. C. electrodes for the smooth stable arc which eliminates the weld spatter. The slag from this type of electrode is easily removed, but the electrode is not recommended for the vertical-down position. Slagging and cleaning is found to be much easier than the slag removal from the lime coated type. To minimize the

loss of chromium when welding stainless steel, welding should be done with a short arc and high travel speeds. The loss of alloy in the welding of stainless steel is greater when using titania coated electrodes.

NOTE: Welding of stainless steel is simplified when the TIG or submerged welding methods are used.

PROCEDURES

The work must be thoroughly clean before starting to weld, particularly on high quality jobs where maximum corrosion resistance is required. Also clean each bead thoroughly before welding over it.

In flat welding use stringer beads for first pass except on joints with poor fit-up where a slight weave is better. Use either stringer or weave beads for succeeding passes. Hold a 1/8" or shorter arc without sticking or choking it. Tip holder forward in direction of travel. Move as fast as possible consistent with desired bead size.

In vertical-down welding use stringer beads or slight weave. Tip holder down so arc force pushes molten metal back up the joint. Move fast enough to stay ahead of molten pool.

When welding vertical-up use wide triangular weave with 5/32" or smaller electrodes. Make a shelf of weld at bottom of joint and add layer upon layer on it. Do not whip or take electrode out of molten pool. Point electrode slightly upward so arc force assists in controlling the puddle. Travel slowly enough to maintain the shelf without spilling.

In the overhead use a whipping technique with a slight circular motion in the crater to make stringer beads rather than weaves. Tip holder slightly forward in direction of travel and use a short arc. Travel fast enought to avoid spilling.

In all the above positions use currents as low as possible consistent with good arc action and proper fusion.

STAINLESS STEELS

Type	AWS Class	Typical Physical Properties, As Welded	Typical Weld Deposit Analysis
Austenitic	E-308-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 40% to 50%	Carbon .07% Max. Chromium 19.0% Nickel 9.5%
	E-308Le-15, 16	Tensile strength 80,000 to 90,000 p.s.i. Elongation (2") 40% to 50%	Carbon .04% Max. Chromium 19.0% Nickel 9.5%
	E-309-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 35% to 45%	Carbon .10% Max. Chromium 23.0% Nickel 13.0%
	E-309Cb-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 30% to 40%	Carbon .10% Max. Chromium 23.0% Nickel 13.0% Columbium .80%
	E-309Mo-15	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 35% to 45%	Carbon .10% Max. Chromium 23.0% Nickel 13.0% Molybdenum 2.2%
	E-310-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 35% to 45%	Carbon .20% Max. Chromium 26.0% Nickel 21.0%

Type	AWS Class	Typical Physical Properties, As Welded	Typical Weld Deposit Analysis
Austenitic	E-310Cb-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 30% to 40%	Carbon .12% Max. Chromium 26.0% Nickel 21.0% Columbium .80%
	E-310Mo-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 35% to 45%	Carbon .12% Max. Chromium 26.0% Nickel 21.0% Molybdenum 2.0%
	E-312-15, 16	Tensile strength 110,000 to 120,000 p.s.i. Yield strength 80,000 to 90,000 p.s.i. Elongation (2") 22% to 25%	Carbon .15% Max. Chromium 29.0% Nickel 9.5%
	E-316-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 35% to 45%	Carbon .07% Max. Chromium 18.0% Nickel 13.0% Molybdenum 2.25%
	E-316ELC-15, 16	Tensile strength 80,000 to 90,000 p.s.i. Elongation (2") 35% to 45%	Carbon .04% Max. Chromium 18.0% Nickel 13.0% Molybdenum 2.25%
	E-317-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 35% to 45%	Carbon .07% Max. Chromium 19.0% Nickel 13.0% Molybdenum 3.25%

Type	AWS Class	Typical Physical Properties, As Welded	Typical Weld Deposit Analysis
Austenitic	E-317ELC-16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 40% to 50%	Carbon .03% Max. Chromium 18.0% Nickel 13.0% Molybdenum 3.25%
	E-318-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 30% to 40%	Carbon .07% Max. Chromium 18.0% Nickel 12.0% Molybdenum 2.25% Columbium .80%
	E-330-15, 16	Tensile strength 75,000 to 85,000 p.s.i. Elongation (2") 25% to 35%	Carbon .25% Max. Nickel 35.0% Chromium 15.0%
	E-347-15, 16	Tensile strength 85,000 to 95,000 p.s.i. Elongation (2") 35% to 45%	Carbon .07% Max. Chromium 19.0% Nickel 9.5% Columbium .80%
Martensitic	E-410-15, 16	Tensile strength 85,000 to 90,000 p.s.i. Yield strength 55,000 to 60,000 p.s.i. Elongation (2") 30% to 35%	Carbon .10% Max. Chromium 12.5%
	E-430-15, 16	Tensile strength 75,000 to 80,000 p.s.i. Yield strength 40,000 to 45,000 p.s.i. Elongation (2") 30% to 35%	Carbon .10% Max. Chromium 16.0%

Type	AWS Class	Typical Physical Properties, As Welded	Typical Weld Deposit Analysis
Martensitic	E-502-15	Stress relieved at 1325° F. Tensile strength 95,000 p.s.i. Annealed from 1550° F. Tensile strength 79,000 p.s.i. Elongation (2") 22% to 35%	Carbon .05% Max. Chromium 5.10% Molybdenum .56% Manganese .55%
	E-502-16	Welds on air-craft type steels may be heat treated to 180,000 p.s.i. tensile strength.	Carbon .10% Max. Chromium 5.0% Molybdenum .50%

CAST IRON ELECTRODES

NICKEL

This is a coated nickel electrode used to repair cast iron when the deposit must be machinable. This electrode is very ductile and is found to stretch during cooling and, therefore, relieves the stress set up in the welded cast iron. This counteracts the separation action which would be found in most filler rods if used on cast iron.

The arc should be held the same as if welding on mild steel and can be used in all positions for both beading or weaving. D. C. reverse polarity gives a flat smooth bead.

STEEL

Steel electrodes with special coatings are available for welding cast iron but the deposit is not machinable. The deposits are dense, strong and tough. Since mild steel has a higher tensile strength than the cast iron the deposits are actually stronger than the cast iron itself.

When welding, the arc should be held as short as possible without allowing the coating to touch the work. Straight progression stringer beads should be used with D. C. reverse polarity or on the A. C. machine.

BRONZE

With this type of rod the welds, especially in Vee'd joints, tend to resist cracking; therefore, the length of welds can be increased. The wire is of the phosphor bronze type, and the flux coating gives a stabilized arc, although the striking of the arc takes some practice. With this type of rod it is essential to clean each bead before fusing in the next bead where complete passes are made. Peening each bead and allowing the bead to cool before continuing with the next pass will help to eliminate pinholes which can become a welding problem.

LOW HYDROGEN

Although these rods are basically used on steel below the 1.5% carbon content they have been used successfully on various cast iron welding jobs. As mentioned previously, the heat input of this type of rod is such that residual stress can be expected in the parent metal after welding, and unless the casting being welded is heavy enough to resist the stress, then cracking will occur. The finished product will be non-machinable.

ALUMINUM AND BRONZE ELECTRODES

Aluminum

These are dip-coated electrodes which can be used both with metallic and carbon arc welding on aluminum. The coating prevents excessive oxidation and dissolves the aluminum oxides that form. Welding with D. C. reverse polarity and a short arc, just touching the molten pool, will give exceptionally high quality welds. The melting rate of the electrode is high and little heat is put into the parent metal making it necessary, under certain conditions, to preheat before welding. The electrodes in this type of welding should be perpendicular to the work in order that the melt-off of the flux will be effective. Slag should be removed completely, even to the point of using hot water and wire brushing. Out-of-position welding with this type of electrode is not recommended.

Bronze

This is also a coated electrode which is used on D. C. reverse polarity for welding ferrous metals and bronze or copper. Where the parent metal of the bronze and copper type are heavy material, it is usually necessary to preheat in order to compensate for the high conductivity rate. High heats are recommended on those metals which tend to evolve gases in order to reduce porosity. Manipulation of the electrode should be such that the arc tends to flare back over the molten metal and thus keeps it in the molten condition long enough so that the trapped gases can escape. If work is to be finished machined, the parent metal should be somewhat under-cut before welding so that the machined work will be done on the deposited metal which will then be free of porosity.

HARDSURFACING ELECTRODES

Under this heading we will present all facets of the term hardsurfacing.

The work output is increased when a method of hardfacing is applied to new and used metal parts that wear. The length of usefulness of a wearing part will increase and the equipment will operate more efficiently with less down time.

Hardfacing is the process of putting thin layers of wear resistant material on the required parts by means of the metallic arc welding equipment.

TYPES OF WEAR

Abrasion is the most common type of wear, but impact as well as corrosion will limit the length of service of many machine parts. The student welder, at this point, should be informed that rods suitable to resist wear, created by one of the above types, will not be satisfactory to compensate for another problem.

Abrasion, impact and corrosion cannot only be detrimental to machine parts separately, but can combine with each other to create further difficulties. It is, therefore, necessary to not only know how materials should be applied but also to know the right type of materials which will overcome the problem.

ABRASION

This is caused by:

(1) A rubbing action against an abrasive such as gravel, sand or other similar material.

(2) The action of metal parts in contact with each other in a rolling, rubbing or sliding manner. The introduction of an abrasive material with these would hasten wear.

IMPACT

The surface of the material becomes deformed, cracked or chipped due to the continual pounding action of parts during operations. The impact on parts can be light or heavy, constant or at intervals.

CORROSION

This is the chemical reaction on materials and oxidization of steel which could be increased by heat.

In most applications, more than one of the above factors are at work simultaneously and it is then necessary to evaluate the relative importance of each. The final selection of the hardsurfacing material frequently becomes a compromise because, generally speaking, electrodes which have maximum abrasion resistance have minimum impact resistance. Therefore, it is necessary to choose the material which has maximum abrasion resistance and also has enough impact resistance to withstand the pounding on the part in service.

Prior knowledge of what the part is and what the function of the hardsurfacing will be as well as knowing the type of wear, will simplify the selection of hardsurfacing material.

When steels are alloyed as high as 50% of the material in the steel, the properties of the steel are changed. This improves hardenability and resistance to chemical attack as well as elevates the temperature of oxidation. The student should understand that since high carbon steel decreases in ductility the impact it can absorb would also decrease. The more carbon in the steel the more brittle it becomes and the more susceptible to cracking. For this reason high carbon steels cannot be treated, and when exceptional properties are required in hardsurfacing, only alloyed steels can produce these properties.

The cooling rate after the application of hardsurfacing materials will influence the properties of the deposit. Fast

cooling can be detrimental or beneficial to the deposit of surface layer depending on the materials used. Fast cooling usually gives a more abrasive resistant material than the slower cooling method, but more caution is required in the control of cooling as the alloy elements are increased in the steel.

TYPES OF HARDSURFACING STRUCTURES

MARTENSITIC

This is a hard type grain structure with little ductility but relatively good abrasion resistance. The material deposited is magnetic, and controlled cooling is necessary.

AUSTENITIC

This is soft and tough material structure. This material will work harden at the surface but remain tough and soft below the surface materials. It is non-magnetic and has good abrasion resistance. A high carbon austenite is manganese steel. Unlike manganese steel the low carbon austenite stainless steel is less abrasive resistant and will not work harden readily. The student should understand that in the austenite deposits the hardness does not necessarily indicate the abrasive resistance of the material.

SEMI-AUSTENITIC

This type of structure consists of both martensitic and austenitic materials. It is found to be good in abrasive resistance, which has little affect by the cooling rate, so important to its hardness.

CHROMIUM CARBIDE (HIGH CARBON)

This type of material is high in carbon and produces

a carbide type of deposit which is high in the abrasion resistant quality but only fair in impact. If the carbon is alloyed with the chromium, the result will be a hard matrix of austenitic or martensitic materials in the form of chromium carbide which will be very hard, but will not respond to heat treatment.

APPLICATION

Preparation for Welding

Preparation for welding includes cleaning the work, preparing the surface, filling depressions, build-up and preheating when required.

Cleaning the Work

Rust, grease, oil and dirt must be removed from the work before welding begins.

Preparing the Surface

Some base metals work harden, squash over or crack in service. This surface should be repaired before depositing hardsurfacing materials. One method is to grind off the top thin layer of worn out metal. Another method is to deposit the layer of mild or low alloy steel on the part before proceeding with further hardsurfacing.

Filling Depressions

Some areas of working surfaces spall or wear away faster than other portions. If an even surface is desired on the finished part, these depressions should be rebuilt before applying hardsurfacing.

Build-Up

"Build-Up" is a low alloy deposit between the

original surface of the part and the higher alloy hardsurfacing. It is used because it is unadvisable to use more than two layers of the high alloy hardsurfacing material.

Preheating

Preheating is the means of satisfactorily welding many steels so that failure does not occur.

In the case of very hard steels with high internal stresses, preheating tends to relieve the stresses and reduce the effect of the thermal shock of welding. On any hardenable alloy steel, preheating slows the cooling rate so that there is less opportunity for the formation of brittle structures and further, it provides a more uniform cooling so that fewer stresses are built up in the part.

TYPES OF ELECTRODES

Electrodes to Resist Wear from Maximum Abrasion

These electrodes are of the chrome carbide type. Some are coated tubular electrodes applied in the usual method with the metallic arc process. Deposits of these electrodes cross-check on cooling to relieve shrinkage stresses and have good resistance to corrosion and high temperature oxidation. Some are powders which are spread over the area to be surfaced and fused to it with a carbon arc or carbon torch. They have a minimum ad-mixture, highest abrasion resistance and can be deposited in very thin layers or on thin edges.

Electrodes for Buildup on Carbon Steel and for Hardsurfacing to Resist Wear from Rolling and Sliding Friction

These low carbon martensitic electrodes resist rolling and sliding friction. Because of their relatively low

hardenability, they are also used for build-up operations on steel parts prior to finishing layers of hardsurfacing materials.

Electrodes for Buildup on High Manganese Steel and for Hardsurfacing to Resist Wear from Severe Impact

These electrodes give fully austenitic deposits that will withstand severe pounding without failure. The deposits are 11 - 14% manganese steel. They contain high carbon and work harden rapidly. Manganese deposits are widely used for build-up on manganese steel castings where they are frequently covered by two layers of more abrasion resistant hardsurfacing materials. The stainless steel electrodes have excellent corrosion resistance and are used as surfacing deposits to resist corrosion. They are also frequently used to insure a good bond between a base metal of doubtful quality and subsequent hardsurfacing deposits. They will also provide a cushion for increased impact resistance.

Electrodes to Resist Wear from Both Abrasion and Impact

This type of electrode produces a semi-austenitic deposit which has good resistance to both abrasion and impact. Its abrasion resistance is relatively unaffected by welding procedure, but its hardness will vary considerably depending on cooling rate. A 600° F. preheat produces a deposit that is almost entirely martensitic. Faster cooling rates produce deposits that have more austenite.

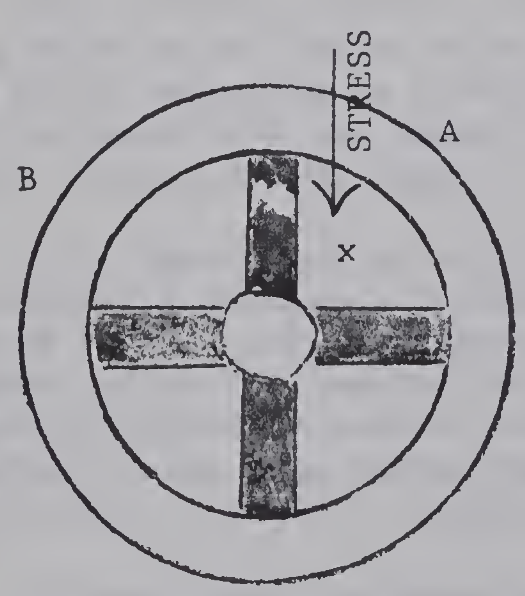
Electrodes for Hardsurfacing Tool Steels

High carbon, high alloy, martensitic type of electrodes have exceptionally good edge strength and are most widely used on tool steel applications.

CAST IRON

The carbon content of cast iron, being a minimum 1.5% as compared to the .15% maximum content in mild steel, creates a welding problem with cast iron. The cast iron has a high compression strength, but it is very low in tensile strength and ductility, which gives the material a high crack sensitivity. Any stress which tends to pull the material apart rather than compress it together will cause a break due to its lack of ductility and low tensile strength.

As mentioned previously, the welding procedure on the wheel hub as illustrated created expansion in the prepared crack on heating, prior to welding. On cooling, the material will contract and any stress set up will have a compression action which the rigid cast can withstand. The welding procedure for the broken wheel should be clearly understood by the welding student before other cast iron welding jobs are considered.



NOTE: Arrow shows stress push rather than pull on cooling.

Since cast iron is a poor conductor of heat it can be realized that local heating creates local expansion which will cause a great deal of stress. Stress which could create a crack or break can be caused by:

(1) Stress in the original casting procedure of the part.

(2) The localized method of arc welding or other heating procedures.

Cast iron is difficult to weld due to violent thermal processes of rapid heating by the arc welding method and the rapid cooling caused by the heat of the molten pool absorbed by the cold cast iron. Carbon pickup from the parent metal which is absorbed into the weld deposit has a tendency through dilution to make the weld metal also very sensitive to cracking. Since most absorbed carbon is deposited at the end of the bead it is at this point that fracture occurs.

To overcome crack sensitivity the preheating method of the entire part is desirable followed by a slow uniform cooling.

RULES FOR WELDING CAST IRON

Make certain that the work is clean and free of defects. If a hole is drilled at each end of the crack, the danger of the crack spreading is eliminated. Grinding to the bottom of the crack with the exception of a slight land will facilitate welding in some cases.

If a great deal of welding is to be done it might be advisable to preheat. Preheating temperature is usually around 500° F. Welding should be completed once it has started since the cooling and reheating process will create uneven shrinkage stresses which could cause cracking of the finished weld. The welded part should be allowed to cool slowly when the job is completed.

On both small or large repairs the operator may choose to weld without preheating. This is the procedure used on such things as cast iron automobile blocks or heads. With this procedure the operator must keep both the weld and the work cool at all times. The beads should be very short and not more than 2" in length. Cracking and shrinking can be prevented during this type of welding if the 2" bead is immediately peened. The crater of each placement bead should lay on the top of the previous bead, and this is done by the

backstep welding method. Do not start the next 2" bead until the previous bead is completely cooled.

METHOD OF LOCATING HAIRLINE CRACKS

To trace out fine crack outlines in cast iron, one of the following procedures could be adopted:

(1) Ferromagnetic Powder

This powder is brought into the vicinity of the magnetized cast part, and the particles in the powder are attracted to minute poles on each side of the crack which in turn forms a visible indication of the crack due to the magnetic field being broken or distorted.

(2) Temper Colors

The material to be welded is sand blasted or cleaned by some other method in order to leave the metal bright. Heat is then applied near the crack, and the temper colors will fan out in color sequence until, on reaching the crack, they are disrupted and the color sequence becomes separated.

(3) Fluorescent Inspection

This is used on non-ferrous as well as ferrous type materials. Fluorescent materials are rubbed over the cracked areas and then rubbed off. Ultraviolet light is used to expose the fluorescent materials glowing in the interior of any crack. This fluorescent material can be combined with ferromagnetic powder to better outline the cast iron cracks.

TESTING AND SEALING CAST IRON WATER CONTAINERS

After welding on a cast iron water jacket it can be tested safely with cold water. Cast iron, unlike ductile materials, cannot be peened to stop a seepage leak appearing in the weld area.

The welder would be well advised to use external or internal sealants rather than to do further welding if small leaks appear. Many internal sealants on the market today are very satisfactory for sealing surface seeping in cast iron containers.

External sealants such as various smoothon cements, monoclinic sulphur and fast drying enamel will penetrate and seal small weeping areas in a weld.

TYPES OF PATCHES USED ON BROKEN CAST IRON CONTAINERS

The welder must consider the effects of expansion and distortion created through welding when patching cast iron with steel. The steel patch used in this type of repair must be much lighter than the parent metal cast iron in order to eliminate as much stress through contraction pull as possible.

The design of the steel patch which allows for dimensional changes due to the heat can compensate for any weld pull which might fracture the less ductile cast iron.

The dished patch, which under pull would be flexible if made of light material, will be quite satisfactory in most applications. Lap welds, however, should only be used on the curved cast surfaces and all butt welds on flat surfaces. Flanged patches are best prepared for use in edge welds.

REASONS FOR PIPE WELDING

Pipe welding, instead of threading, has many advantages

other than labor saving time and labor saving costs. Fittings are now available for pipe welding at a lower cost than the threaded type. Contractors feel that 50% can be saved on the cost of materials alone.

Thinner pipe, which is cheaper, can be used when welding is involved. Threading would cut the effective thickness of the wall of the pipe a great amount, and heavier pipe would therefore be necessary. Thread cutting reduces the strength of pipe which could be overcome by welding. Since the pipe, fittings and welds become an integral part of the system, leaks due to vibration and stress do not occur. When welded there are no step-ups or step-downs as in the threaded system, and inside the pipe, turbulence, clogging and erosion are eliminated. The roughing-in of a system is faster with less manual labor and there is easier nesting and insulation application for better appearance.

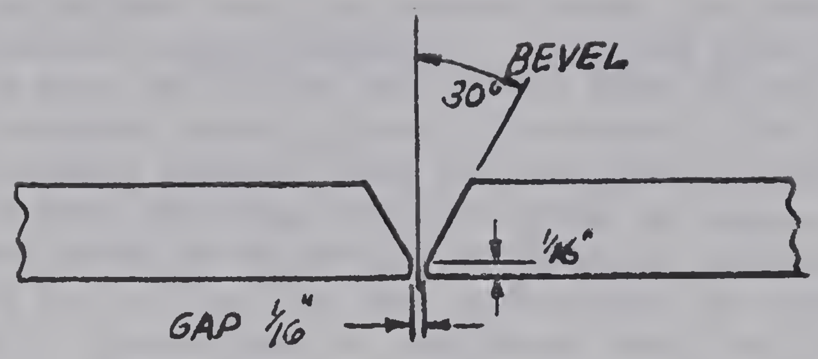
PIPE WELDING PROCEDURES

Field welding of pipe with a wall thickness over ½" is completed vertical-up while pipe with a wall thickness less than ½" is completed in a vertical-down position. Practically all pipe welding within plants are completed vertical-up.

Preference for the above procedures depends not only on advantages and disadvantages, but on the skill and experience of the operators available.

VERTICAL-DOWN

This is a method where high currents and faster travel speeds can be used where joints are completed with several small beads. Porosity and poor fusion can be eliminated if the prepared bevels are kept clean. The bevel should consist of a 30° included angle with a 1/16" root face and a 1/16" gap as illustrated.



Line up clamps are used to hold the pipe sections together. Usually welding takes place with two operators working on opposite sides of the joint. In the down position the first pass is a drag pass. In order to penetrate and fuse properly the current setting and gap must be correct. The second pass is called a hot pass and must be applied to the well cleaned stringer bead with sufficient current to ensure good penetration. Wrong travel speed must be considered as the cause of slag inclusions and poor appearance.

The filler passes are introduced with a slight weave motion, and all slag must be cleaned before applying each successive bead in order to eliminate slag inclusions.

The cover pass must be high enough to overlap the original groove and must be kept narrow to distribute the stress. Undercut and pinhole porosity can be controlled through the use of proper heat settings.

VERTICAL-UP WELDING

This type of position welding requires the use of lower currents and slower speeds to produce a joint with fewer but heavier beads. The slower travel speed eliminates gas holes but larger gaps are necessary; and, therefore, more electrodes per joint are used. Preparation is the same as in vertical-down except where back-up rings are used a root face is unnecessary. The gap must be increased to the diameter of the electrode coating for the best results.

In the vertical-up, the welder tacks the pipe in position in four places on equal segments. Starting from the bottom, the weld is made up to the top on one side of the joint and the same procedure takes place on the other side by the same operator. When a back-up ring is used, penetration must be complete on both the ring and pipe lips or edges. After cleaning the first pass, the second pass is introduced near the bottom; but not at the same spot where the first pass was started. Fusion must be completed into the first pass. The final and finish passes should not be over excessive in bead height and should overlap the groove by about 1/8".

TYPE OF ELECTRODES

An E6010 is sometimes used as a stringer bead followed by low hydrogen beads. By welding a stringer bead down with the E6010, a higher speed and a smaller gap is possible.

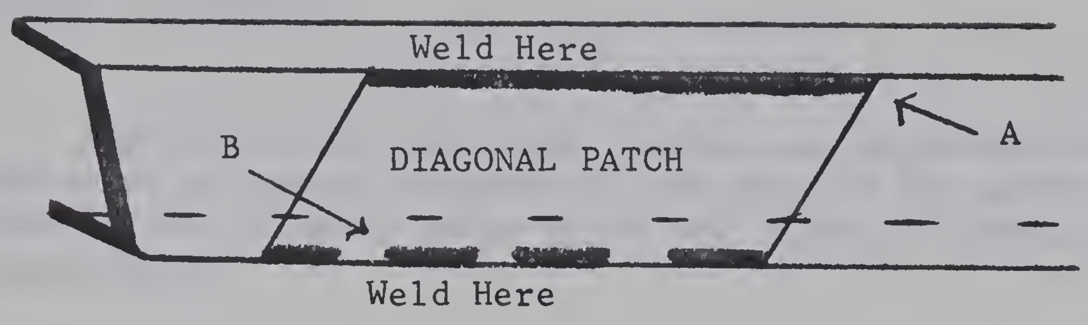
Low hydrogen electrodes give a hydrogen free deposit which will eliminate the use of preheating and will allow for easier cleaning than would be possible with the commonly used E6010. The low hydrogen electrode is used vertically-up or in a horizontal position and always with a back-up ring.

WELDING REPAIRS AND FABRICATION

TRAILER AND TRUCK FRAME

Patches

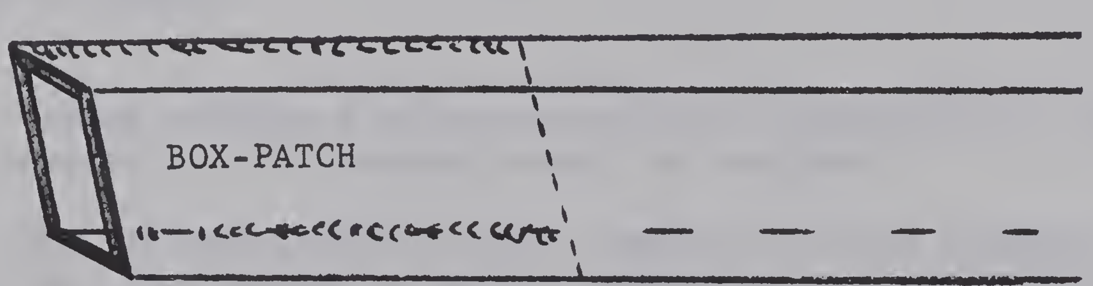
In fabrication and repairs where reinforcing is necessary all types of reinforcing should be thinner than the parent metal, and welding of the reinforcing should only be completed along the horizontal with the ends left free for flexibility, as illustrated below.



This type of reinforcement is known as a scab patch, and when used on trailer or truck frames the welding can be continuous as shown above at "A" or intermittent as at "B" depending on the length of the patch. This type of patch can also be used on the top or bottom flange of truck frames where weak hollow depressions have been left due to hot or cold work repairing.

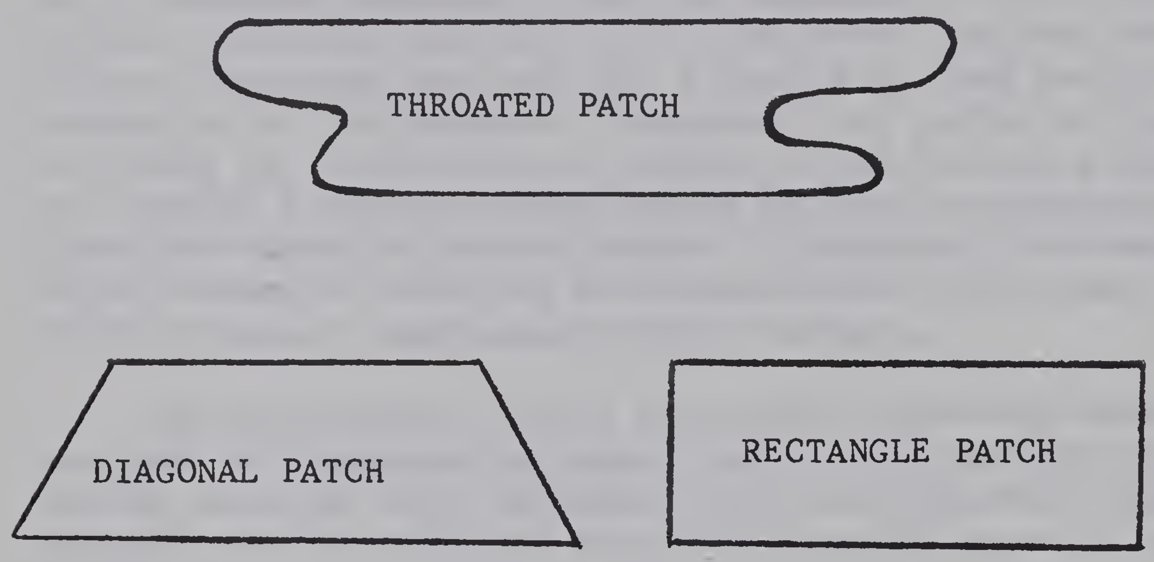
Over reinforcing, like overwelding does not strengthen the repair job but can do harm by elimininating the metal's required flexibility.

The box-patch is used when a strong crack resistant reinforcement is needed on a frame section such as a truck frame. The rectangular material used forms a hollow box section on a frame to any desired length. Welding can be continuous or intermittent.



SHAPES OF PATCHES

The previously mentioned patches can be shaped in such a manner as to resist cracking at the ends of the patch. Keeping flexibility in mind, three types are listed in order of suitability.



NOTE: Do not weld the ends of the above.

CAUSE OF BREAKS

Before welding a break or crack in a material, the cause and reason for the breakage should be studied.

The following definitions, explanations and examples will help the student to better understand why metals fail.

(1) Reversal of Stress

When a piece of wire is subjected to back and forth bending procedures for a long period of time it will

break or part. A dynamically loaded structure, unlike a static load structure, is one subjected to shock and vibration which creates reversal of stress, and metal under this stress, like the wire, ultimately fractures.

(2) Fatigue

Metal fatigue is classed as a long term process with eventual failure. The wire eventually reached the point of fatigue and failed. If the wire had been bent in one direction and left for a period of time before rebending in the opposite direction, the period of time required for separation or fatigue would be much greater as long as a period of hesitation or rest was taken before the rebend or stress action. Therefore, the metal under stress is found to stand more when rested than if it is stressed continuously until failure.

Fatigue failure occurs after work hardening which was due to reversals of stress over a long period of time. As the material work hardened, the ductility was lowered, and the tensile strength was raised to the point of failure.

Failures of this type are usually straight through the thickness of the material at a 90° angle. Minute cracking points, being created over a long period of time appear and are visible as various rust shades after the metal separates at the crack.

This type of material failure should not be reinforced, especially on truck or trailer frames. Normalizing for some distance on either side of the weld after repairs have been completed would be advisable.

(3) Work Hardening

Certain steels are said to work harden which, in turn, makes them more useful. This term does not necessarily mean eventual metal failure. Work hardening is reached prior to the fatigue point, and if caution is used and work hardening is not carried too far, failure will not occur. By means of normalizing we can avert fatigue in work hardened metal and the welder must be

prepared to use such a technique under certain conditions.

(4) Design

Some machine parts have a residual stress problem when designed to be welded in a jig. Faulty design problems are limited due to engineering know-how and techniques, but should one arise, the welder must consider various welding remedial procedures.

(5) Impact

Light impact, if continuous, will cause metal to work harden and eventually fail. This fatigue failure will be welded and normalized rather than welded and reinforced.

Single severe impact caused by accidents also makes trailer and truck frame repairing necessary. Some frames can be repaired without the need of reinforcement. Cold pounding and pressing of frames could require normalizing procedures to eliminate any work hardening.

Depressed sections caused by expansion through heating and pounding can be scab patched or the depressions can be cut out and new straight surfaces welded in.

ALTERATION AND FRAME REPAIRS

When repairs or alterations are to be made on truck or trailer frames certain precautions are necessary.

(1) Take off gasoline tanks or fill the tank full of gasoline and cover the top vent cap with wet sacking.

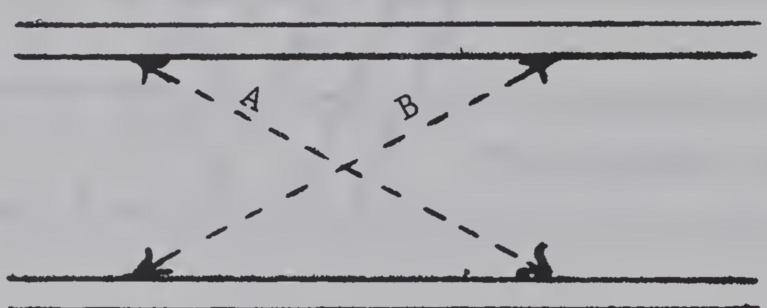
NOTE: If air is excluded an explosion cannot take place.

(2) Vent rear end housings, oil pans, gear boxes and any other chamber where accumulated gases could

form due to the welding heat. Remove a battery if welding sparks can reach that area. Batteries will explode.

(3) Keep fire extinguishers close at hand for all types of fires since upholstery, gas lines and electric wiring can ignite if subjected to the right heat at the right time.

After all safety procedures have been checked and completed, the welder should assess the damage to be repaired as well as the cause of such damage. The welder should tram all frames at regular intervals in order to keep frame alignment. To tram the operator makes diagonal measurements from opposite points on a frame to opposite points on the other side as illustrated.



TRAMMING; LINE A = B

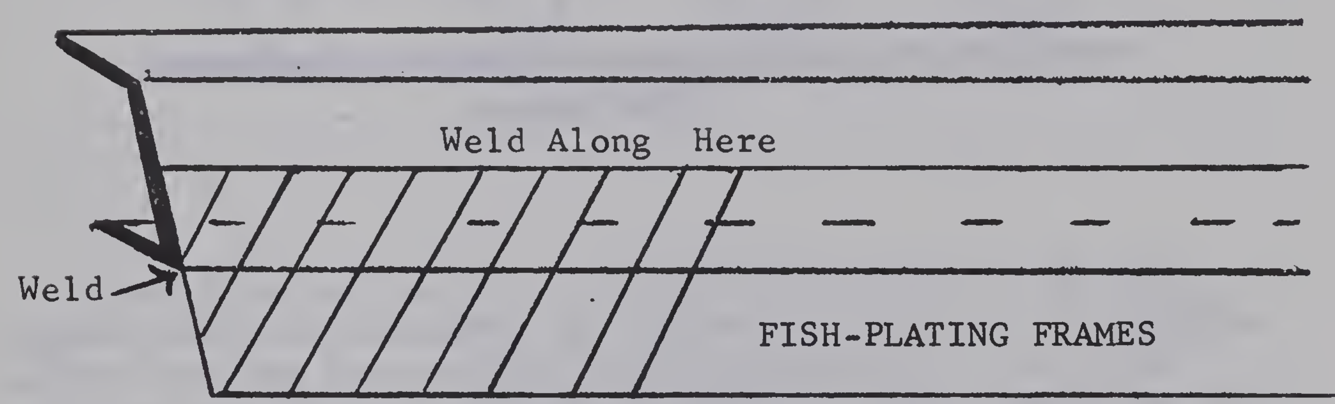
Where the frame has broken due to fatigue, welding from both sides with an E6010 or low hydrogen electrode is permissible with the bead build-up not exceeding more than 10% of the frame thickness. On thick frames a double "V" preparation can be ground with opposite root passes fully penetrated. As mentioned previously, critical weld areas can be moved away from the weld area by the normalizing method. As in all fatigue failures, reinforcing is usually unnecessary.

Frame failures can, at times, be eliminated by what is known as fish-plating. This is a method of reinforcing an original frame with additional material by means of riveting or welding to the frame.

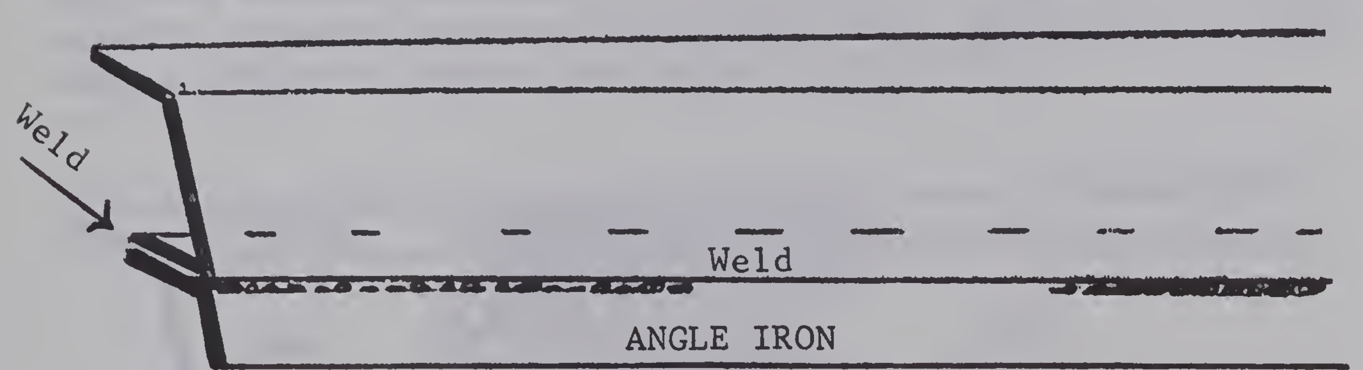
Three methods of frame fish-plating are:

(1) Welding a bar stock horizontally along the frame face and allowing a portion of same to protrude below the main frame. The frame prepared in this manner will resist twisting which would tear out spring hangers, cross members, etc.

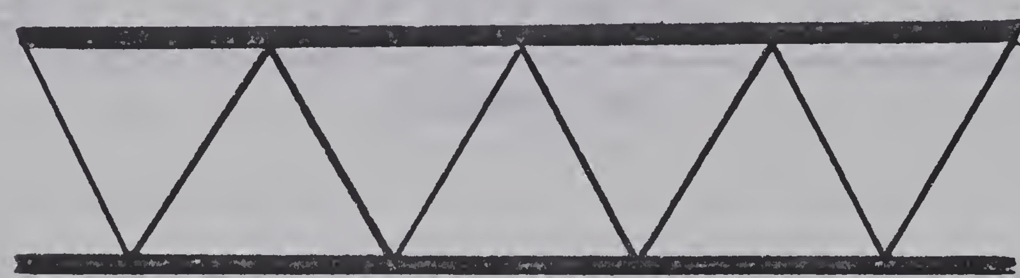
As illustrated, welding is completed continuously or intermittently in the horizontal and horizontal overhead position.



(2) Angle iron reinforcing can be welded to the lower flange of the frame by means of continuous or intermittent welds in the horizontal position. This type of fish-plating is very satisfactory and easy to install.



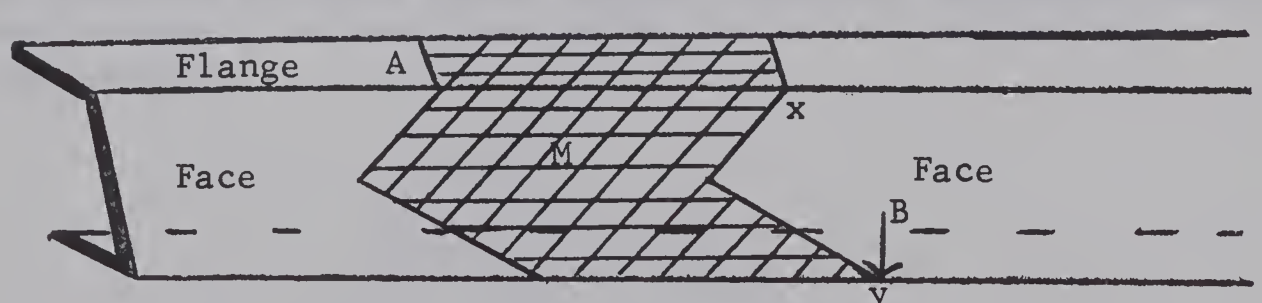
(3) The Warren Truss method of fish-plating is satisfactory but more expensive. It consists of two flat pieces of bar stock the width of the flange of the truck frame. Bridging by means of pipe or round stock is welded between the flat bar stocks to make an I beam shape and when completed is welded to the bottom flange of the frame in the same manner as the angle iron above.



WARREN TRUSS

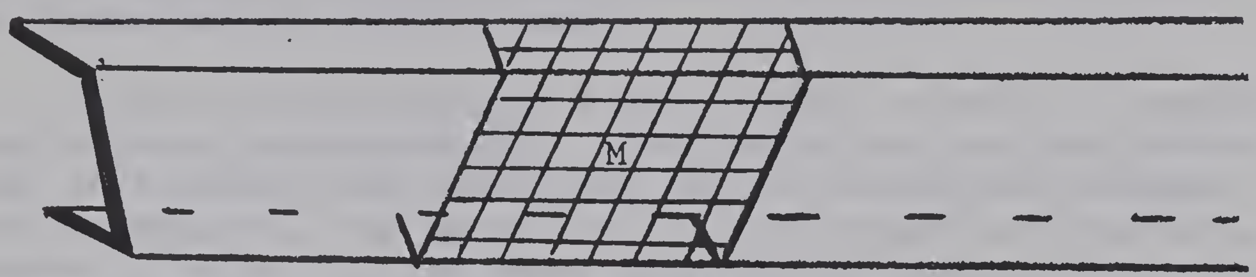
The fish-tail joint as illustrated below is the most popular cut for extending or shortening frames. The flanges at "A" and "B" are usually cut perpendicular or at a 90° angle to the flange, although different angle variations are permissible. The fish-tail cut on the face of the frame is usually cut at a 45° angle with points "x" and "y" placed in such a manner as to not be opposite to each other which will offset top and bottom flange welding and give a less critical area.

The size and length of "M" would depend on the size of the frame and the length of the extension required. It should be noted that only one cut in the frame is necessary for extension purposes but for frame shortening, two cuts are necessary in order to remove the excess portion "M".



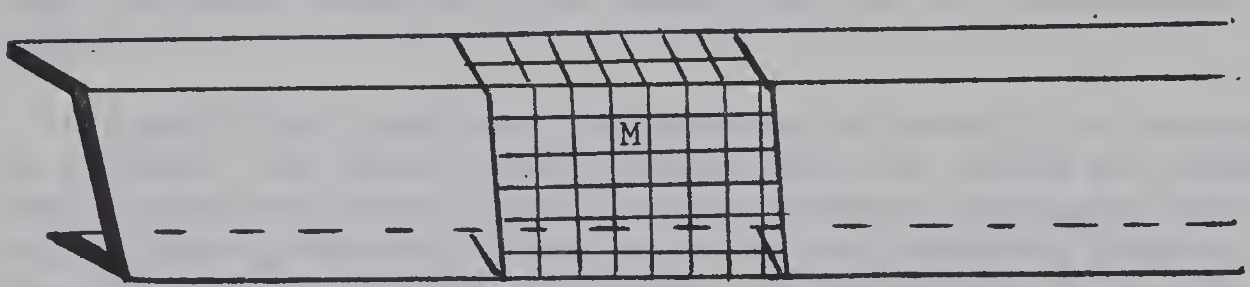
FISH-TAIL CUT

The diagonal cut illustrated below, like the fish-tail, gives a similar weld strength advantage.



DIAGONAL CUT

The illustrated square cut saves on material and is faster and cheaper, but critical areas in the weld vicinity are common. Reinforcing by means of box sections would protect the critical areas of the weld.



SQUARE CUT

Where frames are shortened using a diagonal or fish-tail cut the welder will not be required to use additional reinforcing procedures in most cases. The welding operator would be well advised to box in the frame well past the weld areas by means of suitable patch designs, whenever extension pieces are inserted, unless fish-plating is to be used for job completion.

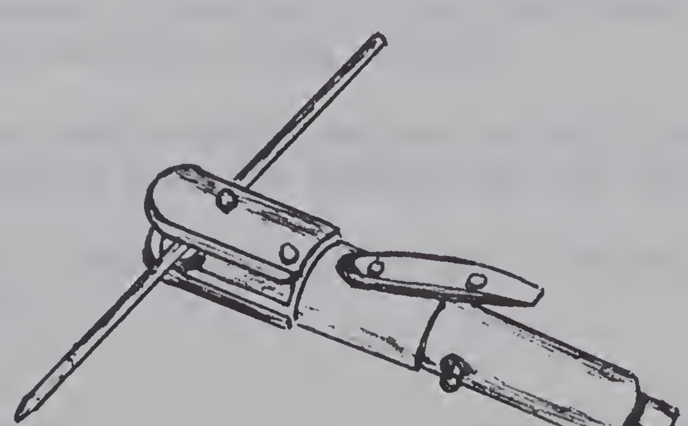
ARCAIR TORCH

The Arcair torch will cut, bevel, gouge, groove, pierce or flush away any kind of metal.

This torch uses current from a welder, a special electrode, and ordinary compressed air. Both current and air are fed to the torch through the same line. An arc is produced between the electrode and the metal to be cut or gouged, and the metal instantly melts. At the same time, jets of compressed air come out of the torch head and blast the molten metal away. The resulting cut or groove is bright and clean, requiring no further preparation.

Air flow is controlled by an "on-off" valve in the torch handle. The torch head rotates for instant positioning of the electrode to any desired angle. The metal parts of the torch are specially selected for best electrical efficiency and long life. The insulators, lever and handle are of high-impact, heat-resistant materials for rugged service and low maintenance.

On critical work where absolutely no porosity or cracking is allowed, the Arcair torch grooves out the cracks and removes porous areas quickly. Arcair cuts, grooves, or flushes off any surfacing material since it is not an oxidizing process. The low heat input does not affect the properties of the base material. Where it is necessary to under-cut the parent metal before applying the initial deposit, the electrode should be held at a relatively flat angle to the work and oscillated from side to side to the desired width in order to get a clean ductile base metal for deposit.



QUESTIONS TO SECTION IV A

1. Assuming a welder uses a 60 cycle current, explain alternating current.

2. What is direct current?

3. On what type of welding machine could a polarity change be expected?

4. What polarity would there be on a D. C. welder if the electrode was attached to the positive pole of the machine?

5. Arc blow is experienced when a welder used a machine with what type of current?

6. Give the definition of tensile strength.

7. What is meant by the ductility of metal?

8. How is penetration as a welding term best described?

9. Explain izod impact.

10. Name two (2) methods used for a hardness test.

11. Describe a weave bead.

12. How would one describe a root pass?

13. Name the two (2) types of voltage in a welding circuit.

14. Give a short definition of the ampere as it pertains to welding.

15. What purpose is served by the rectifier in an A. C. selenium rectifier type welder?

16. What size cable would you use on a 300 amp. welding machine for distance from the machine of 100 feet?

17. With what type of electrode can a quick check be made for polarity?

18. The E6010 electrode has a high ductility range. What percent elongation in 2" would you expect from this rod?

19. It is said that two-thirds of the heat of the arc is associated with the positive pole; therefore, which polarity would give the greatest penetration?

20. By what two (2) basic ways is molten metal transferred across the arc?

21. What is residual stress?

22. What are the effects of post heat treatment on the following when multiple bead welding is used to fill the weld joint:

    (a) Grain Structure
    (b) Residual Stress
    (c) Distortion
    (d) Tensile Strength
    (e) Ductility

23. What are dipped electrodes?

24. In what position can the E6010 electrode be used?

25. What are the following low iron powdered coated rods called E6018 and E7018?

QUESTIONS TO SECTION IV B

1. Name three (3) types of rods used for cast iron welding and yet are not made of cast iron.

2. What is the average tensile strength of cast iron?

3. What is the biggest single drawback in the cast iron welding process?

4. In arc welding of cast iron what knowledge must the welder have when running beads?

5. What are two (2) methods of tracing out cracks in a cast iron part when preparing for the welding process?

6. Name three (3) types of steel patches that can be used to repair cast iron.

7. What are the names of the two (2) basic types of distortion?

8. What does a welder mean when he speaks of using a strong back?

9. Why would the operator, in some cases, use a stagger welding technique?

10. What is a dynamically loaded structure?

11. How does fatigue differ from work hardening?

12. What are the three (3) types of automobile frames mentioned in Section IV?

13. What electrode and what thickness of build-up should the welder use in cases of dynamic loaded truck frame failure?

14. What do you, as a welder, consider the three (3) causes of breaks in frames?

15. What are the names of the three (3) basic types of preparation for joints when shortening or extending a truck frame?

16. Name two (2) types of reinforcing patches.

17. What are the three (3) variations of patch shapes as listed in Section IV?

18. When should a welder weld across the frame face?

19. What procedure should the welder follow after welding a frame section broken through fatigue or work hardening?

20. Would reinforcing be considered necessary in the shortening of most truck frames?

21. Of the three (3) basic types of preparation for joints in the shortening and extending of truck frames, which would offer the least wasted materials?

22. Which dimension of a carrying member is the greatest single factor determining its load carrying ability?

23. After welding fatigue cracks, should the operator resort to reinforcing for extra strength?

24. How can the welder recognize fatigue breaks?

25. Does work hardening necessarily mean fatigue?

ANSWERS TO QUESTIONS TO SECTION I

1. An awareness of:

   (a) harmful rays
   (b) poisonous gas
   (c) explosive materials
   (d) hot metal and slag

2. Clothing can be:

   (a) leather
   (b) asbestos
   (c) wool
   (d) denim

3. The rays are:

   (a) visible light
   (b) ultra-violet
   (c) infra-red

4. Welding operators usually prefer green lenses.

5. A number six (#6) lens is usually preferred, but in some cases, it depends on the operator's vision.

6. The distance from the arc to the operator is considered to have an intensity of ten times that of the sun.

7. The infra-red rays are thought to be capable of affecting the eyes in this respect.

8. Portable shields are used in open areas to protect other workmen from the harmful rays.

9. The engine exhaust must be conducted to the outside atmosphere.

10. The two (2) basic burns are:

    (a) superficial or surface
    (b) deep burns

11. The hot iron should be marked "HOT" by means of chalk.

12. The term used to describe eyes burned by ultra-violet rays is known as arc-flash.

13. Purge or Purging is the removal by cleansing.

14. Before an explosion can take place, we must have all three (3) of the following:

    (a) combustible gas or gases
    (b) supporting air or oxygen
    (c) ignition

15. When purging by means of engine exhaust fumes, we would find:

    (a) Carbon sparks from the exhaust line could touch off an explosion.
    (b) Carbon Monoxide gas, being poisonous, creates added danger.

16. Static electricity in the steam itself could be the cause of ignition and create an explosion.

17. In welding gas tanks, the following is recommended:

    (a) Purge tank with steam or hot water, or
    (b) a strong caustic soda, then
    (c) fill the tank with water to the level of welding.
    (d) Make sure the vents are open above.

18. The zinc fumes can cause metal fume fever.

19. Class B fires consist of flammable liquids such as oil, grease, paint, etc.

20. Approved extinguishers carry the label of the Underwriter's Laboratories and/or Factory Mutual Laboratories.

ANSWERS TO QUESTIONS TO SECTION II

1. The five (5) basic welding joints are:

   (a) Butt
   (b) Tee
   (c) Corner
   (d) Lap
   (e) Edge

2. The three (3) basic welds are:

   (a) Groove
   (b) Fillet
   (c) Plug

3. The Groove Weld could consist of:

   (a) Single V
   (b) Single U
   (c) Plain Butt
   (d) Single Bevel
   (e) Single J

4. The Plain Butt is also known as a Square Groove.

5. Plug and Slot Welds are sometimes called Rivet Welds.

6. Bead Welds can be classified as:

   (a) Stringer Bead
   (b) Weave Bead

7. Intermittent Welds are short welds of equal length spaced at equal intervals along the joint.

8. The various positions in which welding can be done are:

   (a) Overhead
   (b) Vertical
   (c) Horizontal
   (d) Flat

9. The Horizontal Position is the position in which the plane of the weld is level or parallel to the earth.

10. The tail of the welding symbol is used for designating the welding specifications, procedures or other supplementary information to be used in making the weld.

11. When the weld symbol is placed on the reference line away from the reader, the weld will be made on the side of the joint opposite to where the arrow points.

12. When a black dot is placed where the arrow makes a definite break from the reference line, it means the weld will be made in the field away from the shop.

13. The size of the weld is shown on the left of the weld symbol, the length is shown on the right.

14. A Flush or Convex Contour symbol accompanied by the letter:

    G - means grind
    C - means chip
    M - means machine

15. When Dual Bead Weld symbols appear on a reference line, it indicates the section is to be built up.

16. Weld Faults can be classed as:

    (a) Dimensional
    (b) Surface Faults
    (c) Internal or Defect Faults
    (d) Notching Effect

17. Gas inclusions in welding are also referred to as:

    (a) Porosity
    (b) Blowholes
    (c) Piping

18. Slag inclusions are entrapped slag within a bead or between passes within a multipass weld.

19. Fillet, Bevel and J Groove welds shall be shown with the perpendicular leg always on the left.

20. When a circle is placed where the arrow makes a definite break from the reference line, it means weld all around.

ANSWERS TO QUESTIONS TO SECTION III

1. Generally speaking, the width of the affected zone in a gas weld will be greater than in arc weld.

2. One of the important factors in determining the physical properties of steel is the percent of carbon.

3. Steels that become relatively hard when cooled from their upper critical temperature in air at room temperature are referred to as "air-hardening" steels.

4. Metallography may be defined as the study of the structure of metals.

5. The three factors which are most important in the control of the structure of a piece of steel are:

   (a) Composition
   (b) Heat Treatment
   (c) Mechanical Treatment

6. Ferrous metals are metals having a high iron content and they are usually magnetic.

7. Non ferrous metals are those metals which contain no appreciable amount of iron.

8. Metals can often be fairly closely classified by:

   (a) Appearance
   (b) Chip Test
   (c) Flame Test
   (d) Spark Test
   (e) Weight

9. Carbon is the most important alloying element.

10. Carbon steels are usually divided into:

    (a) Low Carbon Steels
    (b) Medium Carbon Steels
    (c) High Carbon Steels
    (d) Tool Steels

11. There are three (3) types of cast iron in general use:

    (a) White Cast Iron
    (b) Malleable Cast Iron
    (c) Grey Cast Iron

12. Internal stress within material is called Residual Stress.

13. The reason for annealing steel is to lower its hardness, as an aid to machining or further work.

14. The term tempering covers that operation which involves a reheating of a hardened part in order to toughen it, reduce brittleness and to obtain the exact degree of hardness desired.

15. In flame hardening steel above 0.50 carbon the danger of spalling and cracking is increased, therefore, it is not recommended as a general rule.

16. Steel is magnetic until it reaches the critical temperature, then it is non-magnetic.

17. Case hardening consists of two operations:

    (a) Carburizing
    (b) Hardening

18. Fine-grained steel is strong while coarse-grained steel is weak.

19. Forged steel has a more homogeneous structure than cast steel, and is less fragile and free from internal stresses.

20. Zinc 40% and copper 60% alloyed is tobin bronze.

ANSWERS TO QUESTIONS TO SECTION IV A

1. Alternating current is electric current which reverses its direction at fixed intervals according to the number of cycles of the current being produced or used.

2. Direct current is electric current that always flows in the same direction.

3. Polarity change can only be accomplished on a direct current machine.

4. When electrode is attached to positive pole the polarity is called reverse.

5. Arc blow is experienced at certain times when a D. C. welding machine is used.

6. Tensile strength is the ultimate pull a material will stand and is expressed in thousands of pounds per square inch.

7. Ductility is the ability of a material to stretch or deform under load without breaking.

8. Penetration is the amount that the crater or weld digs down into the joint.

9. Izod impact is a test to determine the resistance of a material to fracture when rigidly held and struck with a hammer. It is expressed in foot pounds.

10. Hardness is tested by the Brinell or Rockwell method.

11. A weave weld is a bead made with side motion as well as motion in the direction of travel.

12. The root pass is the first pass or the penetrating bead made at the root of a weld.

13. In a welding circuit we must consider open circuit voltage and arc voltage.

14. The ampere is the unit of electric current flow. It determines penetration and burn-off rate of the electrode.

15. The rectifier, consisting of copper and selenium plates, serves the purposes of collecting all positive charges of current on one bead and all the negative charges on the other bead. The result is that the welding current is D. C. or direct current.

16. The size of cable depends on the rating of the welding machine and the distance the welding is to be done from the machine. A 300 amp. machine at 100 feet of distance needs a 310 cable size.

17. Any rod XX10 such as E6010 or E7010 will do a test for polarity. If it reacts normally, your electrode is fastened to the positive pole.

18. The E6010 rod has a minimum tensile strength of 60,000 p.s.i. with a 24 - 30% elongation in 2" which generally favors the higher percentage.

19. The electrode positive or reverse polarity gives greater penetration.

20. Molten metal is transferred across the arc by globular transfer and spray transfer.

21. Residual stress is stress within the weld after cooling.

22. Post heating on multi bead welds has:

    (a) Little or no change on grain structure.
    (b) No change on residual stress.
    (c) No change on distortion.
    (d) Lowered tensile strength to good.
    (e) Raised ductility to good.

23. Dipped electrodes are rods dipped in liquid flux and dried.

24. In the E6010 the third digit 1 means the rod can be used in all positions.

25. We call E6018 and E7018 low hydrogen coatings.

ANSWERS TO QUESTIONS TO SECTION IV B

1. There is actually only one (1) type of electrode that is made of cast iron, but there are several other types of non-cast iron such as:

   (a) Ferrous Based (Non Machinable).
   (b) Nickel Based Electrodes (Machinable Type).
   (c) Bronze Electrodes (Machinable Type).

2. Cast iron is a rigid material having no ductility and an average tensile strength of approximately 20,000 p.s.i.

3. Because of internal stress set up in the welding of cast iron which could cause cracking, the welder experiences this stress problem as the biggest single drawback.

4. In metallic arc welding of cast iron the beads must be short to keep the heat input down.

5. To trace out the limits of a crack in cast iron use:

   (a) Magnetic Flux (magna flux) or
   (b) Fluorescent Penetrants.

6. The three (3) patches are:

   (a) Flanged.
   (b) Dished.
   (c) Lap.

7. Distortion may be broken into two (2) basic types:

   (a) Dimensional.
   (b) Angular.

8. A strong back is a heavy strong object placed beneath the parts to be welded, and the parts may be clamped directly to it to maintain alignment.

9. The basic principle involved in stagger welding is the spreading of heat throughout the joint.

10. A dynamically loaded structure is one that is subjected to rapidly changing load, reversals of stress and quite often to shock and vibration as well.

11. Fatigue differs from work hardening in the fact that work hardening can be accomplished in a relatively short period of time.

12. The types of automobile frames can be classed as:

    (a) Conventional Frames.
    (b) Heat Treated Frames.
    (c) Integrated Frames.

13. In the case of dynamically loaded truck frame failure weld the frame, preferably from both sides, using E6010 or E6011 electrodes; penetrate completely making sure build-up does not exceed 10% of the thickness of the frame.

14. In general, causes of breaks can be classified as follows:

    (a) Fatigue.
    (b) Impact.
    (c) Faulty Design.

15. The three (3) basic types of preparation for joints of this type are:

    (a) Fish-Tail.
    (b) Diagonal.
    (c) Square Cut.

16. Reinforcing patches are classified as:

    (a) Scab.
    (b) Base-Patch.

17. Variations of patch shapes are:

    (a) Rectangular Patch.
    (b) Diagonally Cut Patch.
    (c) Throated Patch.

18. Never weld across a frame unless it is a break which has to be welded.

19. Where a frame section is fatigued or work hardened, normalize that section.

20. In the shortening of frames, reinforcing is not generally necessary.

21. While there is practically no waste in preparation of the square cut and it is fast and cheap, there still is the disadvantage of a critical area on each side of the weld which travels directly across the frame.

22. The depth of the member is the greatest single factor.

23. Fatigue cracks should not be reinforced as the reinforcing creates "dead moment" at the patch, and will cause further breaking at the ends of the reinforcing.

24. The fatigue fracture generally is straight through the thickness of plate at 90° to the plate surface, and the crack is usually irregular in outline.

25. If the work hardening is not carried too far, then work hardening does not necessarily mean fatigue.